PROCEEDINGS

OF THE

AMERICAN PHILOSOPHICAL SOCIETY

HELD AT PHILADELPHIA

FOR

PROMOTING USEFUL KNOWLEDGE.

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VOL. XLIII. JANUARY, 1904. No. 175.

Stated Meeting, January 1, 1904.

President SMITH in the Chair.

A communication was received from the Société Nationale des Antiquaires de France, announcing that it would celebrate its centenary on April 11, 1904, and inviting the Society to appoint a delegate to represent it on this occasion. The invitation was accepted, and the President subsequently appointed the Marquis de Nadaillac to represent the Society at the celebration.

The Judges of the Annual Election of Officers and Councillors reported that an election had been held on the afternoon of this day, and that the following named persons had been elected to be the Officers for the ensuing year:

President

Edgar F. Smith.

Vice-Presidents

George F. Barker, Samuel P. Langley, William B. Scott.

Secretaries.

I. Minis Hays, Edwin G. Conklin, Arthur W. Goodspeed, Morris Jastrow, Jr.

Treasurer.

Henry LaBarre Jayne.

Curators.

Charles L. Doolittle, William P. Wilson, Albert H. Smyth.

Councillors to serve for three years.

Richard Wood, Henry Carey Baird, Samuel G. Dixon, J. G. Rosengarten.

Stated Meeting, January 15, 1904.

President SMITH in the Chair.

The decease was announced of Alfred R. C. Selwyn, LL.D., at Vancouver, B. C., on October 18, 1902, æt. 78.

The following papers were read:

"On the Phylogeny of the Edentata," by Prof. William B. Scott.

"Herder and Franklin," by Prof. M. D. Learned.

"The Main Facts in Regard to the Cellular Basis of Heredity," by Prof. Thomas H. Montgomery, Jr.

THE MAIN FACTS IN REGARD TO THE CELLULAR BASIS OF HEREDITY.

(Contributions from the Zoological Laboratory of the University of Texas, No. 56.)

BY THOMAS H. MONTGOMERY, JR.

(*Read January 15, 1904.*)

I.

Under heredity we understand the transference to the offspring of qualities of the parent or parents. The interpretation of the phenomena involved constitutes one of the broadest problems in the field of Biology, and has for centuries been the theme of eager discussion. Yet only in the past forty years has there come out any positive knowledge upon the subject, except the making known of certain cases of parthenogenesis and of the occasional difference of reciprocal crosses.

There are obviously two methods of determining the facts of heredity. First, by the intercrossing of different varieties or species, and the determination of the relative influences of the parents upon the offspring. The first fundamental work in this line was done by Mendel in 1865 (*Versuche über Pflanzenhybriden*), who determined a large series of facts for the plant genus *Pisum*, and from the data established a mathematical law for this genus as to the inheritance of parental qualities by the hybrids. This memoir, only some three years ago resurrected from its long obscurity, is to-day occupying the attention it deserves, and has stimulated much work along the same line. De Vries' magnificent work, *Die Mutationstheorie*, demands as well recognition in this respect. But it is clear that such experimental intercrossing, in so far as only the end results of the crosses are considered, can do no more than state the degrees of resemblance of the offspring to the parents, and decide the questions as to the fertility of the hybrids. Important and necessary as it is, it does not go to the root of the matter, and cannot present any empirical analysis of the underlying factors.

For an understanding of these we must turn to the second method, to the examination and interpretation of the intimate structural and growth phenomena of the germ cells themselves, that is, to the

cellular basis. All explanations must remain purely hypothetical until this is done. And here I would call attention, as briefly and concisely as possible, to certain positive results that have been won in the study of the germ cells, and disregard the many fascinating but purely hypothetical views as to the process of heredity.

II.

The statement of the problem must be a very broad one. The fertilized egg gradually cleaves into many cells. These progressively arrange themselves into tissues, and these form organs. By continuing cell division, by change of position and infolding of cells, and particularly by a differentiation of the cells as the development proceeds, the adult organism eventuates. Then from the body of this adult comes an egg, and it repeats the whole involved process. Here are two great fundamental problems: the one, why the offspring resembles the parent? the other, what are the factors of differentiation? On the answer to these problems depends to great extent the explanation of how variations arise and how they are promulgated, that is, the explanation of descent with modification, broadly called evolution. The very subsidiary question of the determination of sex is necessarily also connected with these problems. And all of these questions are inseparable from the one: How far is the adult preformed or prelocalized in the germ cells?

What interests us immediately are the two points: First, has there been empirically determined a particular cellular substance, most intimately connected with the transmission of hereditary growth energies? And second, if such a substance is known, does its behavior during the process of development of the embryo throw any light upon the processes of heredity?

III.

To make the following argument clear, we must call to mind the structure of the mature germ cells and the process of cell division.

The maternal germ cell, the ovum, appears much like any large, unspecialized cell. We distinguish in it a central rounded body, the nucleus, with its surrounding cytoplasm. In the cytoplasm there is a living substance, the protoplasm proper, and various deutoplasmic substances, such as yolk, which serve mainly for the nourishment of the cell. The nucleus is more complex. Travers-

ing the thinly fluid nuclear sap, which fills it, is a delicate network or meshwork of linin threads, and supported upon or imbedded in them masses of a substance called chromatin. In the nuclear sap may be suspended also one or many large rounded bodies, the nucleoli, and numerous minute lanthanin granules. The whole is enclosed by a nuclear membrane.

The paternal germ cell, the spermatozoon, has a very different appearance, and in volume is exceedingly smaller than the ovum. In the case of the sea-urchin, Wilson (*The Cell in Development and Inheritance*) has computed it to be about one half-millionth the volume of the egg, and the difference is many times greater than this in the case of the bird. The history of its formation shows it to be a highly specialized cell with regard to its cytoplasm, which is generally modified to form a locomotory flagellum. But its amount of chromatin is the same as that in the egg cell, though contained in a very condensed form (composing the head of the spermatozoon). At the junction of the flagellum and head there is frequently found a mid-body, a metamorphosed centrosome. Thus there is a division of labor between the two germ cells: the ovum is large to provide the necessary cytoplasm and nourishment for the embryo; the spermatozoon minute and motile in order to reach the ovum.

All cell reproduction is by division of the cell, and the mode of division, which differs very notably from a mere constriction into two, may be briefly recalled. The nucleus of the cell increases in volume, and its scattered chromatin masses group themselves evenly along the linin threads, so that eventually the chromatin seems to be arranged in the form of a long, continuous loop. In the cytoplasm at one side of the nucleus appears a minute body, the centrosome. This divides into two centrosomes, and they wander apart from each other, each through an angle of 90°, to opposite sides of the nucleus. These centrosomes are the dynamic centres of the cell division and exert an influence upon the surrounding cytoplasm, as shown by systems (asters) of cytoplasmic rays converging upon them. Within the nucleus, meanwhile, the chromatin loop has become split through its entire length by an exact halving of each of its larger chromatin masses, and has also broken transversely into a fixed number of segments, the chromosomes, which now are connected together only by linin threads. Then the nuclear membrane dissolves away and a dicentric figure appears

with a centrosome, the centre of an aster, at each pole, the chromosomes grouped together in a plane midway between the poles and with the long axis of each chromosome coinciding with this plane. Then begins the separation from each other of the halves of each longitudinally split chromosome and to opposite poles, probably due to the contraction of linin fibres that connect the chromosomes with the centrosomes. Their separated halves come to lie in two groups, one near each centrosome. Finally, each centrosome loses its influence upon the cytoplasm, the radiations around it disappear, each group of chromosomes forms again a rounded nucleus, the cell body constricts between them to form two cells, and as a result there are two cells each with its own nucleus. The remarkable accomplishment is an exactly equal distribution of the chromatin mass to the daughter cells by a very complex mechanical process.

IV.

Now is there any particular one of these structures that can be determined as the bearer of hereditary qualities? No one has advocated that it might be a centrosome, and, indeed, there is no reason for considering a centrosome to be any other than a dynamic centre. Such a substance must then be in either the cytoplasm or the nucleus.

The earlier views were that this particular substance was located in the cytoplasm (Lankester, 1877; Whitman, 1878; Flemming, 1882; Van Beneden, 1883). But these were hypothetical assumptions and employed not so much to show a special hereditary substance, as rather to explain the progressive specialization of the cleavage cells. Hereditary traits cannot, moreover, be transmitted by the cytoplasm of the spermatozoon, for in some cases (Echinoderms) the whole cytoplasmic flagellum of the spermatozoon is left outside the egg, and only the head and midbody of the spermatozoon penetrate the egg in fertilization. There is also the decisive experiment of Boveri, to which we shall recur, showing that the cytoplasm of the egg cell also does not transmit hereditary traits.

Accordingly the hereditary substance must have its seat in the nucleus, and there is now practically positive evidence that such a germ plasm is the chromatin. The main reasons are as follows:

(1) The exact distribution of the chromatin in cell division, so that each daughter cell receives just half the amount of chromatin

of the mother cell. The longitudinal splitting of the chromosomes is an autonomous act, whereby each small chromatin mass composing the chromosome (though not the smallest visible granules or microsomes) divides exactly into halves, and the whole complex series of changes leading to the dicentric division figure seem to have been evolved simply to effect the equal distribution of the daughter chromosomes to the daughter cells. Whether the cytoplasm divides equally or unequally, the chromatin is always divided and distributed equally. This fact alone has seemed sufficient to most workers to mark the chromatin as the hereditary substance.

(2) The fact that the chromosomes, the accumulations of chromatin during cell division, are fixed in number for all the cell generations of a species. And the strong probability, amounting almost to a fact, that the chromosomes preserve their individual continuity from generation to generation, notwithstanding their great chemical and structural changes during the rest stage of the cell.

(3) The fact that the spermatozoon, in most respects the very antithesis of the ovum, on entering the egg in fertilization brings in just the same amount of chromatin as that contained in the egg. Not only is this so, but Van Beneden demonstrated as long ago as 1883 (*Recherches sur la maturation de l'œuf*) that the spermatozoon brings into the egg just as many chromosomes as are contained in the latter. Since we know that the two parents have an approximately equal influence upon the offspring, and since the chromatin is a substance contributed in equal amount by the two germ cells, it is logical to conclude that this substance is the seat of the hereditary growth energies.

(4) The fact that, despite considerable differences in other respects in their cell divisions, animals and the higher plants show essentially the same behavior of the chromosomes.

(5) The experiment, first made by Boveri, 1895 (*Ueber die Befruchtungs- und Entwickelungsfähigkeit kernloser Seeigel-Eier*), of fertilizing with a spermatozoon the cytoplasm of an egg cell deprived of its nucleus. Such a fertilized egg fragment develops, but shows purely parental characters, probably because all maternal chromatin had been eliminated. And two recent papers by Boveri (*Ueber mehrpolige Mitosen*, etc., 1902; *Ueber den Einfluss der Samenzelle auf die Larvencharaktere*, 1903) have shown, with

their keen critical analysis of the experiments, that the chromatin alone can be considered the bearer of the hereditary traits.

From all these results it is concluded that the chromatin is the seat of the hereditary growth energies.[1]

And from another point of view this is rendered probable. The microchemical study of the cell has shown that the chromatin is the most active substance concerned in cellular metabolism; and experimental work, particularly that of Verworn, shows that a cell deprived of its nucleus, and hence of its chromatin, is unable to build up new substances. The chromatin accordingly, as it is transmitted from generation to generation, carries with it certain definite metabolic energies characteristic of the species. And from this view there is good reason to consider the idea of Delage (*La structure du protoplasma et les theories sur l'Hérédité*, 1895) to be in the main correct, namely, that the offspring is like the parent because it has similar metabolic energies.

V.

There is another series of facts known about the behavior of the chromatin, the hereditary substance, in the germ cells, and a few of them will be touched upon. Oscar Hertwig showed, in 1875 (*Beiträge zur Kenntniss der Bildung, etc., des tierischen Eies*), that the fertilized egg cell contains two nuclei, one belonging to the egg cell itself and one introduced by the spermatozoon. Then Van Beneden (*l. c.*) demonstrated that the spermatozoon brings in just

[1] It has been argued by an English writer whose name escapes me, as does the title and date of his paper, that the linin is the hereditary substance. Active chromatin is never disassociated from linin, but there is always a substratum of linin in each chromosome, and in the rest stage the chromatin is always supported upon linin strands. Hence it was argued that the linin is likewise equally distributed in cell division. This is a good point, but there is a strong objection to it. When the daughter chromosomes separate, in the anaphase, the linin becomes pulled out between every two corresponding chromosomes as a connective fibre, and in the reconstruction of the daughter nuclei the greater portion of such a fibre is not taken up again into the nuclei. And this fact cannot be used in favor of the intracellular pangenesis theory of de Vries, whereby pangenes are hypothetically supposed to wander out of the nucleus and so determine the differentiation of the cleavage cells, for the connective fibres appear to behave alike in all cell divisions. Thus of the two constituents of the chromosomes, at each cell division some of the linin becomes displaced into the cytoplasm, but all the chromatin passes into the nucleus.

as many chromosomes, and that their mass is the same, as those contained in the egg. Further, it is proved that in normal fertilization only one spermatozoon enters the egg, and that when more than one enters the development is abnormal. The proof that both egg chromosomes and sperm chromosomes have an approximately equal rôle in determining the growth of the embryo has been shown by Boveri (*l. c.*) by crossing different species of sea-urchins, and by analyzing the results of fertilizing an egg with two or more spermatozoa.

Now each act of fertilization would necessarily double the normal number of chromosomes, since the spermatozoon introduces as many as are already present in the egg, were there not some process to obviate this. There is such a process, and it is known as the "reduction in number of the chromosomes." The last two divisions of the germ cells, preceding the act of fertilization and preparing them for it, are known as the maturation divisions; and it has been known for some fifteen years past that in these divisions each germ cell has only one-half the normal number of chromosomes. It is also proven that the ripe egg cell, as well as the ripe spermatozoon, has only one-half the number of chromosomes characteristic of the species. It is further known (since the work of Henking and of O. Hertwig, in 1890) that the processes involved in producing this result are essentially the same in both germ cells. Accordingly, by this preliminary halving of the number in each germ cell before fertilization, the germ cells on conjugation each contribute only one-half the normal number, with the result that the normal number is restored. But this preliminary reduction in number has a broader meaning than this.

Before the first maturation division of the germ cell is accomplished there takes place a pairing of the chromosomes, so that instead of, *e.g.*, four single (univalent) chromosomes there are two double (bivalent) ones (Montgomery, *Spermatogenesis of Peripatus*, 1899). These become so arranged that one of the two maturation divisions results in separating chromosomes that are split longitudinally, just as in any other cell division; but the other maturation division removes entire chromosomes from each other by separating the two chromosomes of each pair, and thereby reduces the number of the chromosomes to one-half. That is definitely known for certain species.

But how account for the preliminary pairing of the chromosomes? It is apparent that each spermatozoon may be called paternal, but not male, and each egg cell maternal, but not female, for the following reason: We have seen that each organism formed by fertilization has a fixed number of chromosomes, half of which were derived from the spermatozoon and half from the egg cell. The germ cells that develop within that organism, be they spermatozoa or egg cells, accordingly have an equal number of chromosomes from each parent. Therefore, the spermatozoon contains maternal as well as paternal chromosomes, and the egg cell paternal as well as maternal chromosomes. And, therefore, each germ cell has in equal measure the hereditary substance of both its parents.

Now the process of pairing of the chromosomes, which we found to be an initial step to their reduction in number, has been proved to be a pairing of paternal with maternal chromosomes (Montgomery, *A Study of the Chromosomes of the Germ Cells of the Metazoa*, 1901). In a particular generation of the sperm cell it was demonstrated (and not merely "surmised," as stated by another worker) that paternal chromosomes pair with maternal ones, forming thus double rods instead of single ones; it is probable, but not yet demonstrated, that likewise in each egg cell, of the corresponding generation, paternal chromosomes pair with maternal. Thus in the reduction division, which displaces the two elements of a pair, a maternal chromosome separates from a paternal in each pair, but not so that all the paternal chromosomes pass into one cell and all the maternal into another.

These facts which we have learned about the chromatim lead to a conclusion that for its probability approaches a fact. That is, that the different chromosomes in a germ cell have each their particular values. Roux (*Ueber die Bedentung der Kerntheilungsfiguren*, 1883) was the first to postulate that the chromatin cannot be hereditarily the same throughout the length of a chromosome, for otherwise its equal longitudinal splitting would be without meaning. In other words, each particular portion of a chromosome would represent a particular hereditary value. Not only is this probable, but it is also probable that one chromosome has hereditary values not found in the others. For we have seen that each germ cell has a set of maternal and a set of paternal chromosomes, and that in a particular generation those of the one set pair with those

of the other (Montgomery, *l. c.;* Sutton, *The Chromosomes in Heredity*, 1903). The two that pair are of corresponding volume (as brought out especially by Sutton), and sometimes of corresponding form (Montgomery, in a paper now in press). Because they are thus similar in volume and form, it is at least possible that they are similar in hereditary value. So Sutton has ably argued that when the two of a pair, a maternal and paternal chromosome of corresponding volume, separate from each other in the reduction division, chromosomes of like hereditary quality become separated into separate cells, so that no mature germ cell shall contain before fertilization two chromosomes having similar hereditary values. And this is the best reason yet given in explanation of the peculiar reduction division.

VI.

Finally, we may ask how far these facts agree with the germplasm theory of Weismann.

Some eighteen years ago, Carnoy (*La cytodiérèse chez les arthropodes*, 1885) showed, and he was the first to do so, that two kinds of cell division occur, namely, a transverse splitting of the chromosomes and a longitudinal splitting. That transverse splittings of chromosomes should occur was directly opposite to the prevalent view of the time, to the effect that only longitudinal divisions take place. Carnoy was far ahead of his day, and while this most important memoir of his then and for years afterwards met with only rather scornful criticism, we must now grant him his proper place as the discoverer of the reduction divisions.

Weismann, in 1887 (*Ueber die Zahl der Richtungskörper und ueber ihre Bedeutung für die Vererbung*), prophesied, clearly without knowledge of Carnoy's work, and in conformity with the ideas of Roux (1883, *l. c.*), that in addition to the longitudinal splitting of the chromosomes, the "hereditary equal division," there would be found to occur in certain generations of the germ cells a "hereditary unequal division," either by a transverse division of the chromosomes or by a separation of entire chromosomes from each other. A number of the students of the maturation phenomena of the germ cells have empirically demonstrated this. Weismann's reduction division is the one where entire chromosomes become separated from each other. Equally, confirmation has been brought of another of his cardinal postulates, the con-

tinuity of the germ plasm. To be sure it is known that the germ plasm, the chromatin, is not an eternally unchangeable substance, as Weismann at first postulated. But the chromatin persists from generation to generation; the continuity of the germ plasm is what to-day is being termed the continuity of the chromosomes, and these continue from generation to generation, maintaining their individuality, just as much as a particular cell of one generation may be said to be represented by a particular cell of another.

Only some half dozen years ago, in the course of the conflict over the germ-plasm theory of Weismann, no workers upheld the occurrence of the reduction division except the school at Freiburg and one or two others. There even appeared a paper, presuming to be decisive, entitled "The Facts of Chromosome Reduction *versus* the Postulates of Weismann" (J. E. S. Moore, 1897). Since that time there has been much new research and by the comparative method, perhaps the safest of all methods, and the mass of evidence is now strongly corroborative of Weismann's two cardinal postulates. So to-day Weismann can point to the actual confirmation of the fundamental portion of his germ-plasm theory.

Stated Meeting, February 5, 1904.

President SMITH in the Chair.

The following papers were read:

"The Babylonian and Hebrew Accounts of the Creation, in the Light of Recent Criticism," by Prof. Morris Jastrow, Jr.

"The Miocene Diabase of the Santa Cruz Mountains in San Mateo County, California," by H. L. Haehl and Ralph Arnold, communicated by Prof. J. C. Branner.

MAP
showing distribution
of the
MIOCENE
DIABASE
of the
SANTA CRUZ MOUNTAINS
in
San Mateo Co
CAL.
scale
Miles
by
H. L. Haehl & Ralph Arnold.
Topography from U.S.G.S.
Miocene Diabase
Miocene Basalt
REDWOOD CITY
Purisima Creek
Lobitos Creek
Sierra Morena
Bear Creek
Dry Creek
Clear Creek
Ellicott's Grove
Bear Creek
Hat Ranch Creek
Alambique Creek
Redwood Creek
Alpine Creek
Pomponio Creek
San Gregorio
San Gregorio Creek
La Honda
Woodside
Portola
Redwood Canyon
Alpine
Pescadero
Pescadero Creek
Butano Creek
Butano Canyon
Big Basin
Big Basin Redwoods State Park
Big Basin Redwoods
Big Basin Redwoods State Park

THE MIOCENE DIABASE OF THE SANTA CRUZ MOUNTAINS IN SAN MATEO COUNTY, CALIFORNIA.[1]

BY H. L. HAEHL AND RALPH ARNOLD.

(*Read February 5, 1904.*)

INTRODUCTION.[2]

The presence of the basic eruptives in the Santa Cruz Mountains of San Mateo County, California, and portions of Santa Clara and Santa Cruz Counties, was first noted in 1865 by J. D. Whitney. In discussing the geology in the vicinity of Searsville, Whitney says:[3]

"In the bed of the creek (one mile west of the ridge in which the coal mine is situated) were, among the boulders of sandstone, some fragments of syenitic granite and of a basaltic rock, which latter is said to cap a few of the highest points of this ridge." Whitney's party also passed over the divide from San Mateo to Half-moon Bay, noting the Cretaceous and Miocene strata and the Montara granite exposed along the road, but seem to have overlooked the diabase exposures on the east and south of the granite outcrop.

W. L. Watts in a paper[4] on San Mateo County says: "At some points basaltic rocks have been observed, and on the San Gregorio Rancho the Field Assistant of the Bureau noted and obtained specimens of vesicular dolerite, the vesicles of which were filled with petroleum."

[1] Published by permission of the Director of the U. S. Geological Survey.

[2] The work of which the results are given in this paper was done while the authors were post-graduate students of geology in Stanford University, under the direction of Dr. J. C. Branner. The authors wish to acknowledge their indebtedness to Dr. Branner for suggestions regarding the field relations, especially of the tuffs and associated rocks, and to Dr. J. P. Smith for suggestions relating to the petrographical work.

The names used in the lists of fossils in this paper are those commonly applied to the respective species by the West Coast paleontologists. Owing to the imperfect state of our knowledge regarding the nomenclature of the California Tertiary fauna, there is a probability that some of the names used are erroneous: the writers, therefore, reserve the privilege of revising any or all of the names if future study shall warrant it.

[3] *Geological Survey of California*, Vol. I, p. 71, 1865.

[4] *Tenth Ann. Rept. Calif. State Mineralogist*, p. 586, 1890.

FIELD RELATIONS.

General Relations of the Diabase.

The exposures of the diabase have been traced for a distance of approximately thirty-two miles in a generally southeasterly direction from a point near the San Mateo-Halfmoon Bay road, on Pilarcitos Creek, in San Mateo County, to a point on the headwaters of Lompico Creek, four miles east of the town of Boulder Creek, in Santa Cruz County. There is also a basaltic outflow exposed near Stanford University, which is probably closely related genetically to the diabase. The exposures east and south of those found at the head of Devil's Canyon are not shown on the map, as, with one exception, they are of minor importance. The largest exposed areas of the diabase are in the vicinity of Langley and Mindego Hills east of La Honda, and on the ridges between the headwaters of Pescadero Creek and the San Lorenzo River (the latter being outside of the area shown on the accompanying map).

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The whole area presents at the surface a chain of more or less connected patches of diabase, extending approximately parallel to the coast, and also parallel to, but southwest of, the major axis of the Santa Cruz Mountains. The continuity of the patches is hidden by overlying strata and by dislocated masses of country rock and soil to such an extent that the exact relations of the various facies are difficult to ascertain.

It is possible, however, to determine the age of the igneous mass by its relation to the sediments about it. The relations of the stratified rocks of the area under discussion are as follows:[1]

Pliocene { Purisima formation with *Astrodapsis* n. sp., *Lucina acutilineata*, *Nucula castrensis*, *Pecten* 3 n. sp., A, B, and C, *Rostellaria undulata* and *Saxidomus gibbosus*.

Miocene { Monterey shale with *Arca montereyana*, *Callista angustifrons*, *Pecten peckhami*, and *Tellina congesta*.
Vaquero sandstone with *Agasoma barkerianum*, *A. kernianum*, *Pecten magnolia*, and *Turritella hoffmani*.

Associated Sedimentary Formations.

The diabase proper breaks through beds of lower, and perhaps middle, Miocene age; while the associated diabase tuff is interbedded with strata containing a typical lower Miocene fauna and lies below the Monterey shale. The basalt[2] outflow exposed near Stanford University overlies and metamorphoses beds of lower Miocene age, and is overlain by beds containing a fauna very similar to the underlying strata. This evidence indicates the lower Miocene age of the basalt and its probable contemporaneousness with the diabase tuffs of Mindego and Langley Hills. Both the intrusive diabase and the tuff are in many places overlain by the Purisima (lower Pliocene) beds, which show a distinct erosion line at their base, and also often a basal conglomerate made up of diabase pebbles.

[1] An uplifted mass of impure stratified limestone, containing a fauna that indicates its probable lower Eocene age, occurs in the diabase area between the headwaters of Pescadero Creek and the San Lorenzo River. This limestone appears to have no visible stratigraphic relations with the Miocene shales surrounding the diabase.

[2] This basalt is the subject of a paper now in course of preparation by Prof. Milnor Roberts, of the University of Washington.

MIOCENE.—(1) *The Vaquero Sandstone.* The lower Miocene of the area consists of a series two or three thousand feet thick of massive, coarse, yellowish sandstone layers, interbedded with a few layers of varying thickness of dark-colored argillaceous shale, the whole overlain by three or four hundred feet of thin-bedded siliceous shales. The lower part of this series of beds, including most of the sandstone, appears to have the same fauna and occupy the same stratigraphic position as the Vaquero sandstone of the Salinas Valley.[1] The name "Vaquero" will, therefore, be used to designate the lower Miocene sandstone in the area under discussion. The sandstone and shale series is typically developed in the region between the headwaters of Stevens Creek and the lower portion of Peters Creek. Fig. 1 shows a typical section of this area.

The fauna of the Vaquero sandstone series indicates its lower Miocene age. The following fossils, most of which are characteristic of the lower Miocene, are among others found in the Vaquero sandstone on Mindego Creek, Langley Creek, at the head of Stevens Creek, and at other points in the area under discussion:

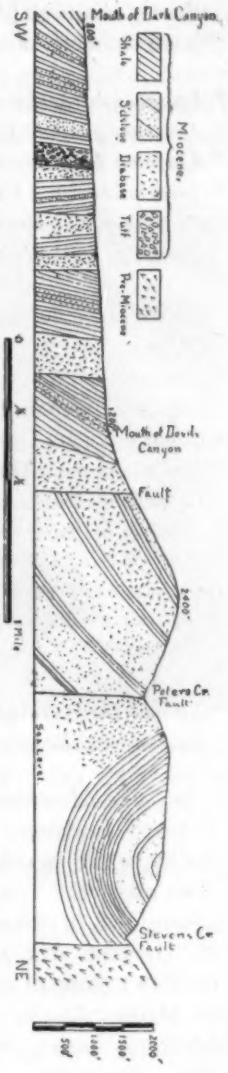

Fig. 1. Southwest-northeast section up Peters Creek and over main ridge into Stevens Creek, showing relations of diabase to Miocene and older formations.

[1] The name for this sandstone was suggested by Mr. Homer Hamlin, and was first used by Dr. Fairbanks in the San Luis folio. This sandstone is typically developed in the Los Vaqueros Valley, near the Salinas Valley, Monterey County.

List of Vaquero (*Lower Miocene*) *Fossils.*—Those marked with a (*) are characteristic, so far as known.—

* *Agasoma barkerianum* Cooper
* *Agasoma gravida* Gabb
* *Agasoma kernianum* Cooper
* *Arca microdonta* Conrad
Balanus estrellanus Conrad
* *Cardium* (*Trachycardium*) n. sp. A.
* *Chione mathewsonii* Gabb,
Chione n. sp. A. (very large)
* *Conus* n. sp. A.
Crepidula grandis Midd.
* *Cuma biplicata* Gabb
* *Dosinia conradi* Gabb
Dosinia mathewsonii Gabb
* *Dosinia* cf. *montana* Conrad
Dosinia aff. *ponderosa* Gray
* *Galeocerdo productus* Agassiz,
Galerus cf. *excentricus* Gabb
* *Glycymeris* n. sp. A. (very large)
* *Lamna clavata* Agassiz
Lucina acutilineata Conrad
Lucina richthofeni Gabb
Mytilus mathewsonii Gabb
Neverita recluziana Petit
Ostrea titan Conrad
Panopea generosa Gould
Pecten estrellanus Conrad
* *Pecten* (*Chlamys*) n. sp. E.
* *Pecten* (*Lyropecten*) *magnolia* Conrad
Pecten (*Plagioctenium*) n. sp. E.
* *Periploma* n. sp. A.
Psammobia edentula Gabb
* *Pyrula* (?) sp. A.
* *Pinna alamedensis* Yates
* *Sigaretus scopulosus* Conrad
Solen sicarius Gould
* *Tivela ineziana* Conrad
* *Trochita costellata* Conrad
* *Turritella hoffmani* Gabb
* *Turritella ocoyana* Conrad
* *Yoldia* n. sp. aff. *cooperi* Gabb

(2) *The Monterey Shale.* The shales overlying the coarse yellow Vaquero sandstone are in some places thin-bedded, soft and chalky, while in others they are hard, dark colored and somewhat more massive. The white facies of the shale is found overlying the diabase tuff in the region just west of the Langley Hill-Mindego Hill igneous area, while the dark colored facies is found on the northeast slope of the main ridge between the summit and Corte de Madera Creek. These shales represent at least a part of the Monterey series, which is supposed to be of middle Miocene age. The upper part of the Vaquero sandstone series, at least that part showing alternating beds of sandstone and shale with a tendency to grade from the sandstone vertically upward into the shale, may be the inshore equivalent of some of the Monterey shale found at the typical locality in the region around Monterey. This

theory is supported by the fact that, where typically developed, the Monterey shale is between twenty-five hundred and three thousand feet thick and rests on a comparatively thin layer of sandstone, while, in the area under discussion, the relative proportions of shale and sandstone are exactly the reverse. The harder, more flinty shales which appear along the coast are not found in the vicinity of the diabase.

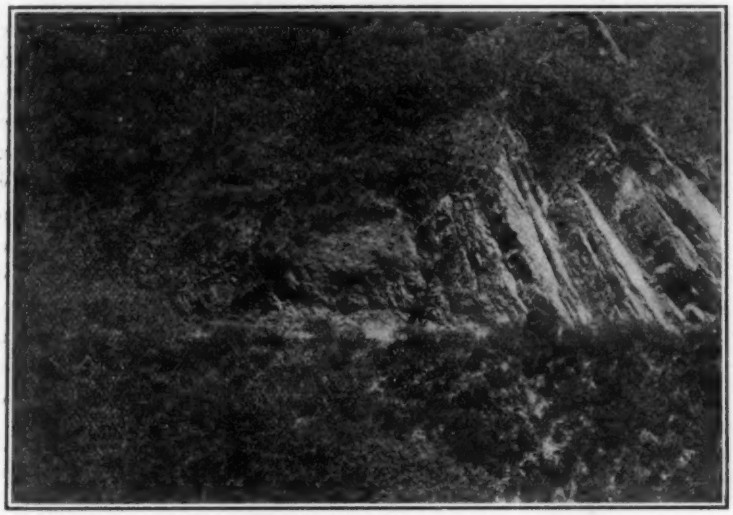

Fig. 2. View on the Searsville-La Honda road three-fourths mile south of summit, looking east, showing the Miocene shale beds resting against the diabase which has intruded them in sill-like dikes. The man points at the contact. Photograph by Ralph Arnold.

The following species of fossils have been found in the Monterey shale within the diabase area:

List of Fossils from the Monterey Shale (*Miocene*).—Those marked (*) are characteristic, so far as known.—

**Arca montereyana* Osmont
Callista angustifrons Conrad
Chione mathewsonii Gabb
**Corbula* sp. A.
Cylichna cf. *petrosa* Conrad
Cythera cf. *vespertina* Conrad
**Diplodonta* n. sp. aff. *serricata* Reeve
**Leda* sp. A. and B.
Pecten peckhami Gabb
Pecten (*Plagioctenium*) n. sp. E.
**Semele* n. sp. A.
Siliqua sp. A.
**Tellina congesta* Conrad

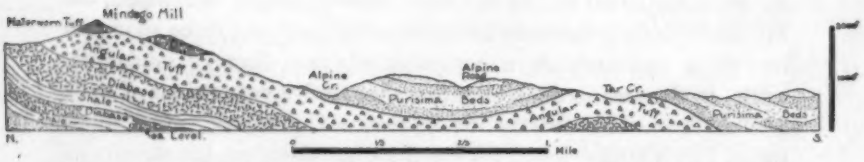

Fig. 3. North-south section from Mindego Hill to Tar Creek, showing the relation of the diabase tuffs to the overlying Purisima beds.

PLIOCENE.—*The Purisima Formation.* Within the area under discussion is an extensive series of conglomerates, fine-grained sandstones and shales for which the writers propose the name "Purisima formation."[1] This name has been chosen because of the typical development of the formation in the vicinity of Purisima Creek, San Mateo County. The Purisima beds lie unconformably upon the Vaquero sandstone and Monterey shale, and at the top grade into beds having a fauna somewhat similar to that of the Merced formation. Its upper limit may be defined as the base of the Merced. In age the Purisima probably represents the lower, and perhaps middle, Pliocene. The individuality of the fauna, stratigraphy and lithology of this formation appears to warrant the application of a new and distinctive name. Fig. 4 shows a typical section of the Purisima formation in the area.

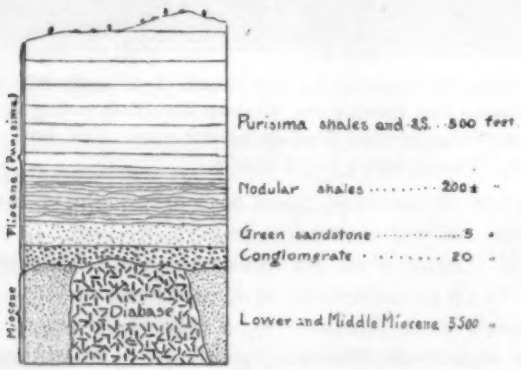

Fig. 4. A typical section in the diabase area.

Stratigraphically the Purisima formation presents a uniform cross

[1] The junior author now has in course of preparation a paper giving in detail the characteristics and faunal relations of this formation.

section throughout nearly the whole diabase area. At its base is the conglomerate, consisting of water-worn diabase pebbles cemented by a more or less siliceous sand. In some places, however, the amount of diabase is so great that it is difficult to distinguish the beds, where badly weathered, from the diabase tuff.

The presence of barnacles (*Balanus*) and of a single specimen of *Pecten* afford the best evidence of the sedimentary nature of the deposit, and fix its origin as marine. The conglomerate is not always of this nature, however. South of the Alpine schoolhouse the base of the Purisima consists of a rather incoherent shale breccia, which had its origin in a talus slope. Part of a *Balanus* was found in this breccia, showing that at least part of the deposit was laid down under water. In places fragments of the Miocene shale, together with hardened sandstone and chert, make up the greater portion of the basal layers, indicating possibly that the Purisima coast line lapped over the intruded area and obtained its materials, not from the diabase area, but from beds to the east of them. The total thickness of the Purisima formation is probably about seven hundred feet. As a rule the conglomerate beds are thin; the thickest of them are about twenty feet in thickness. At some localities, notably at a place a quarter of a mile southwest of the Alpine schoolhouse, the base of the Purisima consists of shale, which rests unconformably upon the diabase.

Above the conglomerate is a thin bed (four or five feet) of soft green sandstone, stained by the chloritic weathering products of the diabase. It contains bones and sharks' teeth and, in some localities, a rich marine invertebrate fauna. Over the green sandstone is a bed of an unfossiliferous, nodular shale of perhaps two hundred feet in thickness.

On the top of the unfossiliferous shale are sandy shales and fine sandstones probably five or six hundred feet thick. While these may readily be distinguished by their lithology, they are also characterized by numerous fossils which are in a fair state of preservation. The following species were gathered from the Purisima beds in different parts of the area under discussion:

List of Fossils from the Purisima (Pliocene) Formation.—Those marked with a (*) are characteristic, so far as known.—

**Arca canalis* Conrad
Arca trilineata Conrad
**Astrodapsis* n. sp. Merriam
Astyris richthofeni Gabb
Balanus estrellanus Conrad
**Buccinum* n. sp. A.
**Calliostoma* n. sp. A.
Callista angustifrons Conrad
**Cancellaria* n. sp. A.
Cardium meekianum Gabb
**Cardium meekianum* n. var. A.
Chrysodomus liratus Martyn
Chrysodomus tabulatus Baird
**Chrysodomus* n. sp. aff. *tabulatus*
Crepidula grandis Midd.
Crepidula rugosa Nuttall
**Cryptomya* n. sp. aff. *californica*
**Dolichotoma* n. sp. aff. *carpenteriana*
Drillia incisa Carpenter
Galerus mammillaris Broderip
Glottidia albida Hinds
**Lævicardium* n. sp. aff. *substriatum*
Leda cf. *fossa* Baird
Leda taphria Dall
Lucina acutilineata Conrad
Lunatia lewisii Gould
Macoma inquinata Deshayes
Macoma nasuta Conrad
Mactra californica Conrad
Mactra falcata Gould
Modiolus rectus Conrad
Mytilus mathewsonii Gabb
Nassa californiana Conrad
**Neptunea humerosa* Gabb
Nucula castrensis Hinds
Olivella intorta Carpenter
Olivella pedroana Conrad
Panomya ampla Dall
Panopea generosa Gould
Pecten expansus Dall
Pecten hastatus Sby. (smooth var.)
**Pecten* n. sp. aff. *expansus*
**Pecten* n. sp. aff. *dilleri* Dall
**Pecten* n. sp. aff. *parmeleei*
**Priene oregonensis* Redfield (n. var. ?)
Purpura crispata Chemnitz
Rostellaria indurata Conrad
Saxidomus gibbosus Gabb
Scutella interlineata Stimpson
Siliqua patula Dixon
Solariella peramabilis Carpenter
Tapes staleyi Gabb
Tapes tenerrima Carpenter
Tellina aff. *congesta* Conrad
Tresus nuttalli Conrad
**Voluta* n. sp.

Relation of the Diabase to the Associated Sedimentaries.

The masses of diabase follow the bedding, particularly in the shale of the lower Miocene series, and it is in between shale beds that most of the diabase exposures occur. Fig. 2 shows some shale beds resting against a large diabase dike which crosses the Searsville-La Honda road near the summit of the Santa Cruz range. The diabase dike in this case was intruded between and followed

the bedding planes of the shale in the form of a sheet. There are some very striking exceptions to the sheet-like occurrences of the diabase, but in general the ready cleavage of the shale along the bedding planes seems to have offered the line of weakness which the intrusive rock followed. Fig. 5 shows a characteristic case of the diabase breaking through the Miocene shales and sandstones. The shale in the middle of the dike in this exposure is slightly darker colored and somewhat harder than the shale beneath the diabase. The sandstone was not affected by the intrusive rock.

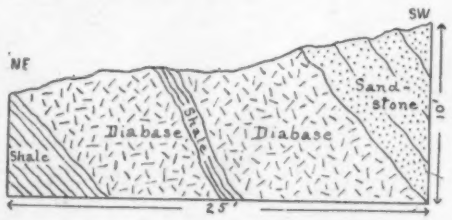

Fig. 5. Vertical section exposed in small ravine on Dornberger's ranch, near the Page Mill road summit, showing diabase intrusive in shale and between shale and sandstone.

Inclusions of sandstone and shale are plentiful and vary from the size of a walnut to masses of hundreds of tons, but no evidence of the alteration of the sandstone has been noted, except in the case of the underlying beds of the basalt near Stanford University. Some well-preserved vertebrate bones and teeth (*Oxyrhina tumula* Agassiz) were found in a sandstone inclusion two feet in diameter about one-half mile north of the Alpine schoolhouse. Fig. 6 shows an inclusion of light yellow sandstone found near the edge of a large diabase dike on the Searsville-La Honda road. Neither the intruded sandstone, which is seen in the upper right-hand corner of the picture, nor the inclusion is in the least altered.

The inclusions of shale are usually somewhat metamorphosed, but the metamorphism is not radical, changes in color and texture being the chief phenomena. An inclusion of shale four inches thick metamorphosed to a hard, brittle flint was found in the diabase on Oil Creek. Similar occurrences were noted at several other localities in the area under discussion. Fig. 7 shows a shale layer which has been slightly hardened by an intrusion of diabase. This is an example of a somewhat common phenomenon.

Fig. 6. Inclusion of sandstone in diabase dike seen in vertical cut beside the Searsville-La Honda road three miles north of La Honda. Photograph by Ralph Arnold.

Fig. 7. View on the Page Mill road two hundred yards south of the summit, looking northeast, showing shale layer slightly hardened at the contact with the diabase dike. Photograph by Ralph Arnold.

An interesting section (shown in Fig. 8) is exposed beside an old road one-half mile north of the Langley ranch house. The diabase at that place breaks through the Miocene shales, following the bedding planes in a general way, but sometimes breaking through the beds. Small inclusions of the shale are found in the diabase, but no alteration of either the inclusions or beds thus intruded was noticed.

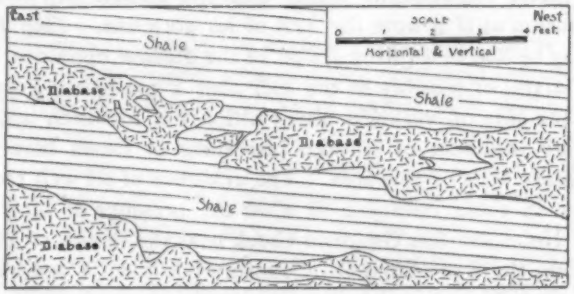

Fig. 8. Vertical section of bank on south side of road one-half mile north of Langley's ranch house, showing diabase intrusion in shale. The shale, which is unaltered, dips into the bank at an angle of 35°.

The Purisima beds (Pliocene) which cover large areas of the diabase are not penetrated by the diabase. This may explain the presence of only small, isolated patches of the diabase along the northern end of the area. Either the Miocene or post-Miocene denudation over the northern end of the diabase area must have been great, or else the Monterey shale must be represented by sandstone over that territory, for there, wherever the diabase is exposed, it is in the Vaquero sandstones, while the Monterey shale appears to be almost lacking. Over this tract a deposition of the Purisima sediments took place after the denudation and covered large areas of the eroded surface of the diabase. At the base of the Purisima beds are conglomerates made up largely of diabase pebbles, and these conglomerates are now exposed in the canyons together with small areas of the diabase in place. The presence of the diabase conglomerate at the base of the Purisima formation, together with the fact that the diabase is intrusive in the Miocene, establishes the time of at least the greater part of the igneous intrusions as later than the middle Miocene (Monterey), and before the Pliocene (Purisima). It is noticeable that the exposures of diabase in sev-

eral instances are low down on the south-facing slopes of the ridges next to the creek beds, but are not visible on the north-facing slopes. This seems to be more than a mere coincidence. The difference of exposure on the two sides of the canyon may be due partly to the thick vegetation and partly to the depth of decomposition and the admixture of organic matter in the formation of the soil on the north-facing slopes.

In general the Miocene shales near the diabase dip away from the intrusion as if it were the axis of an anticline. (See Fig. 2.) This may be due to a lifting action of the diabase upon nearly horizontal strata, or possibly to the fact that a pre-existing axis presented the line of weakness along which the intrusion was made. There are instances of sill-like intrusions or sheets between the sedimentary beds of this area. The evidence of oil well records is available in some instances to show the presence of such sheets. At well No. 1, on San Gregorio Creek near the mouth of Harrington Creek, the San Mateo Oil Company put down a test hole, and a sheet of diabase was encountered at a depth of one hundred feet. A hundred feet deeper the drill passed through the diabase and again entered the shale. This well is about a quarter of a mile from the igneous outcrop on Harrington Creek. Mr. Bell, on whose property another well was bored about ten years ago, is authority for the statement that no diabase was encountered in sinking that well, which is about four hundred yards west of San Mateo Oil Company's well No. 1, and away from the diabase.

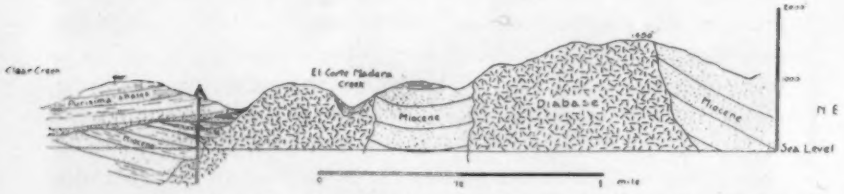

Fig. 9. Northeast-southwest section through the Bella Vista oil well, San Mateo County. Photograph by Ralph Arnold.

The well sunk by the Bella Vista Oil Company on the Bella Vista ranch, north of El Corte Madera Creek, encountered, according to the report of the driller, a fifty-foot stratum of diabase at a depth of four hundred and fifty feet; the drill then passed into shale for another hundred feet, after which it again passed through diabase

for fifty feet and again entered the shale. After passing through a few hundred feet of the shale the well entered the diabase again, and was still in the igneous rock when discontinued. Microscopic slides of the diabase encountered in this well showed it to be very similar to the exposure a quarter of a mile to the east, except that the rock was badly blackened with carbonaceous matter.

The Tuff.

The tuffs associated with the diabase are confined to the Langley Hill-Mindego Hill igneous area, of which they form the major portion. Within this area are also found diabase both of the diabasic and basaltic types, limestone beds, limestone dikes or intrusions, shale and sandstone. It is to be regretted that all of the rocks within this area cannot be differentiated on the map, as their areal distribution would throw much light on the structure of the territory within which they occur. Beds of sandstone containing a typical lower Miocene fauna (given on a previous page) are found between layers of the tuff, while the shales containing *Pecten peckhami*, when associated with the tuffs, are always found above them. This places most of the tuffs in the lower Miocene, with a possibility of their extending into the middle Miocene. Layers of one of the basaltic facies of the diabase are found in such relation to the tuff as would indicate the contemporaneity of the two. This theory is strengthened by the fact that this characteristic basaltic facies, with the exception of the outflow near Stanford University, has been found so far only within the Langley Hill-Mindego Hill igneous area, to which the tuff is confined. The true diabase is later than the basaltic facies and associated tuffs, as it is intrusive both in the tuffs and in shale beds overlying them. The Purisima formation overlies unconformably both the tuffs and their overlying shale beds. (See Fig. 3.)

The tuffs vary in composition from solid masses of basaltic diabase fragments to almost pure limestone, sandstone and shale, depending on the conditions under which they were formed. It is a significant fact that the fragments of igneous rock in the tuff are, in all cases so far noticed, composed of the basaltic facies of the diabase. This is to be expected, as the extrusive forms of the rock would naturally be finer grained than the intrusive ones. The material in which the fragments of igneous rock are imbedded is generally more or less limy, thus showing that the fragments were de-

posited in water at least deep enough to be the habitat of lime-forming organisms. The theory that most of the tuffs were deposited in comparatively deep water is strengthened by the fact that the fragments in most of the beds are angular, which would not be the case had the tuffs been deposited near enough the surface of the water to be affected by the action of the waves.

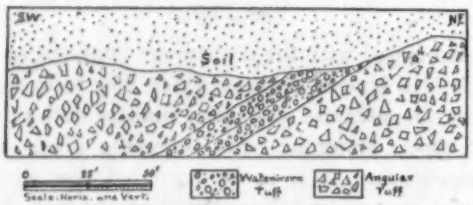

Fig. 10. Section exposed along the Searsville-La Honda road one-fourth mile north of La Honda, showing water-worn tuff interbedded between massive angular tuff.

Fig. 10 shows a section which is exposed along the Searsville-La Honda road a quarter of a mile north of La Honda. Interbedded with the angular tuff is a layer of water-worn tuff about twenty feet thick. The angular tuff appears to have been deposited in the sea in successive layers until it reached near enough the surface of the water to be affected by the wearing action of the waves, when the water-worn layer was formed of the fragmental material. After a time a submergence took place and the top of the deposit was again lowered to such a depth as to be unaffected by the waves, or else the volcanic ejectamenta filled up the shallow sea quite above the water level.

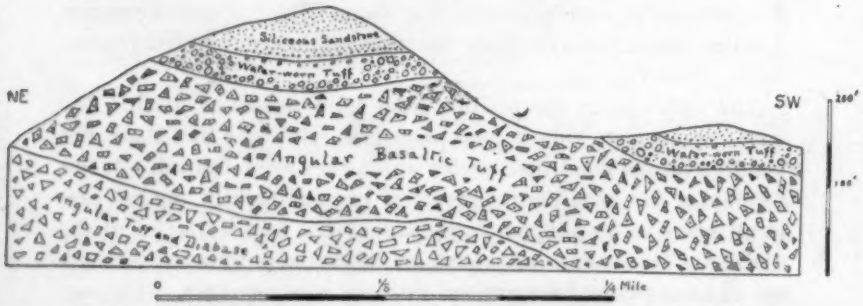

Fig. 11. Northeast-southwest section through the top of Mindego Hill, showing the relations of the different tuffs exposed on it.

Another interesting example of the relation between different facies of the tuff is shown in Fig. 11, which represents a section through the top of Mindego Hill. Here the angular tuff is overlain by a water-worn tuff, which in turn grades by easy stages into a siliceous sandstone. The line of demarkation between the angular and water-worn tuffs is very distinct, the former being dark colored and grading into an almost massive basalt below, while the latter is composed of well-worn fragments of light-colored weathered amygdaloidal basaltic diabase. The water-worn layer grades into a tuff, which is composed of fragments of rock replaced by chalcedony, and then into a fossiliferous sandstone in which some of the fossils and much of the rock have been replaced by chalcedony. Chalcedony and quartz veins and chalcedony-lined cavities are common in the beds above the typical water-worn tuff.

A peculiar tuff, composed of water-worn pebbles of the basaltic diabase imbedded in a fine, brown, ash-like matrix, is exposed on the Searsville-La Honda road just south of the mouth of Langley Creek. Where weathered this tuff so much resembles a true diabase containing pebbles of basalt that at first its origin was quite

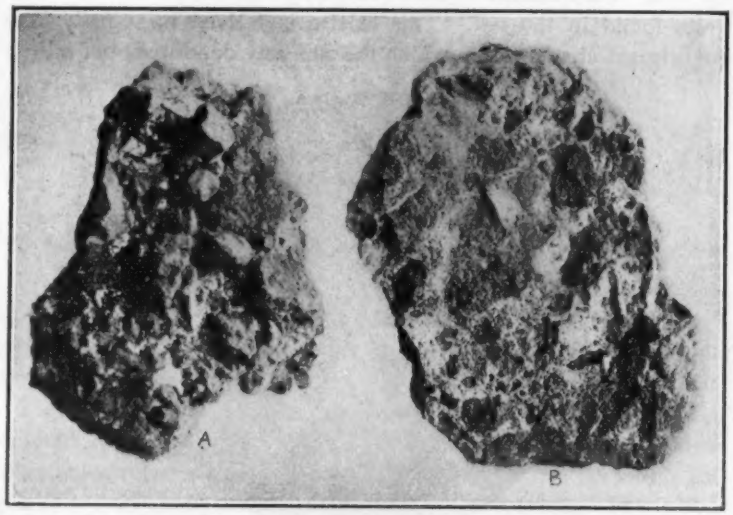

Fig. 12. (*a*) Showing weathered and (*b*) fractured surface of the typical limy tuff from the hill north of the Langley ranch house. Reduced one-half. Photograph by Ralph Arnold.

puzzling. The layer is interbedded between shale layers and at first was thought to be intrusive in the shale, but a later examination showed its true relation to the shales and its clastic origin.

The typical tuff is found in thick beds all along the southwestern and part of the northeastern side of the Langley Hill-Mindego Hill ingneous area. Fig. 12*a* is a photograph of a hand-specimen showing a weathered surface of the tuff, while 12*b* shows a freshly fractured surface. The fragments composing the tuff are of dark-colored basaltic diabase, angular in outline and varying in size from the smallest grains to large masses weighing several hundred pounds. The slides of these fragments show them to be badly weathered, a few feldspars, a little augite and the magnetite and ilmenite being the only recognizable original constituents. The fragments are imbedded in a limy matrix, varying in composition from pure lime to a limy shale. Spheroidal weathering of the tuffs was noticed in one or two instances. Small organic remains are often found associated with the rock fragments in some of the more limy tuffs. Much, and sometimes all, of the lime occurs in a secondary form, as veins of calcite surrounding the fragments or cutting through the tuff. Pure calcite crystals weighing several ounces are sometimes found in the tuff. This calcite is derived principally from the original lime beds in which the tuff was deposited, but a little

Fig. 13. Thin section of diabase tuff, showing secondary calcite vein, (C); patches of secondary calcite, (C′); feldspar, (F); magnetite, (M). × 20. Photograph by Ralph Arnold.

of it may come from a weathering of the feldspars of the basaltic fragments. Patches of isolated calcite are also found in most of the slides of both the basaltic and diabasic rocks. Fig. 13 shows a slide of diabase tuff from the hill east of the Langley ranch house. A secondary calcite vein (C) and small isolated patches of calcite (C') are seen in this slide. Veins of chalcedony and limestone dikes or intrusions are also common in the tuffs.

Limestone Dikes.

One of the most interesting phenomena met with in a study of the Langley Hill-Mindego Hill igneous area is the occurrence of limestone dikes or intrusions in the tuff beds. The best exposures of these dikes are found in the ridge to the north of the Langley ranch house. Figs. 14 and 15 show transverse and longitudinal sections of this ridge, respectively. Similar dikes occur in the tuff

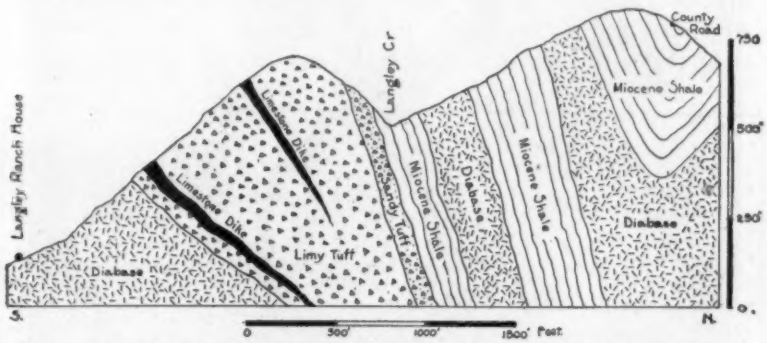

Fig. 14. North-south section through the Langley ranch, showing the stratigraphic relations of the tuffs which contain the limestone dikes.

which makes up the ridge running southeast from the top of Langley Hill, and also in the tuff exposed along the Searsville-La Honda road north of La Honda.

Fig. 15 shows the relative position and size of the principal dikes exposed in the ridge north of the Langley ranch house. These dikes are composed of a more or less pure limestone, in which are generally imbedded fragments of the tuff of varying sizes. The clastic origin of these dikes is shown by their gross structure, their petrographical character and the occurrence of organic remains in nearly all of them. The dikes vary in width from a fraction of an

inch to over thirty feet, and from a few inches to at least one hun-

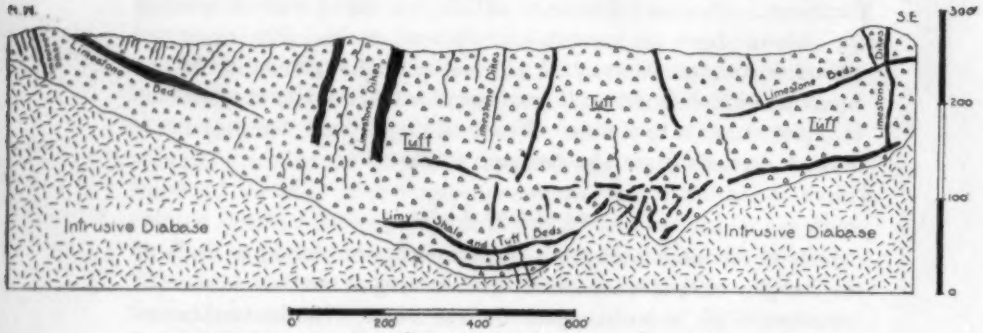

Fig. 15. Northwest-southeast vertical section exposed on ridge north of the Langley ranch house, showing limestone layers interbedded with, and limestone dikes intrusive in, the diabase tuff.

dred and fifty feet in length. Some of them show a kind of flow structure; and a few of them show two systems of joint planes at right angles to each other and both perpendicular to the surfaces

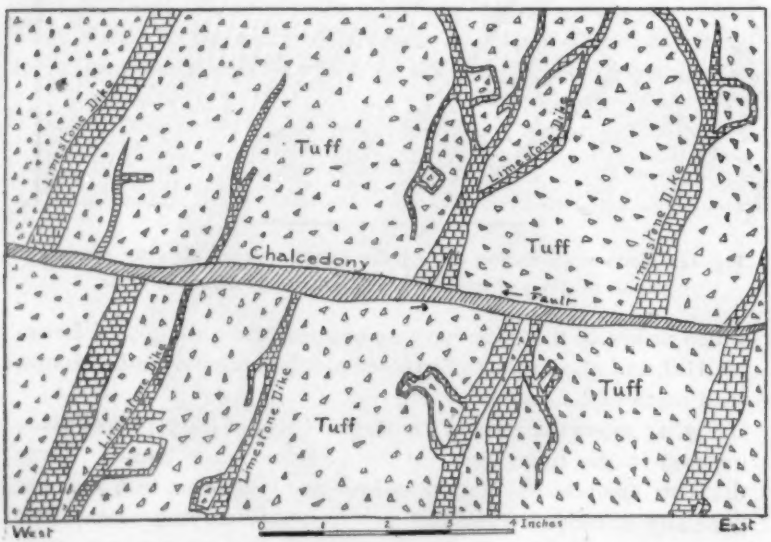

Fig 16. Vertical section showing detail of tuff containing limestone dikes, found on the ridge north of the Langley ranch house. Taken from sketch made in the field.

of the dikes. The surfaces of the dikes are quite irregular, giving a more or less wavy line in section, but the planes of contact of most of the dikes are approximately perpendicular to the bedding planes of the tuff and interbedded limy layers. Some of the dikes extend into the diabase which has intruded the tuff beds. Chalcedony, quartz and calcite form veins and fill cavities all through the tuff, limy tuff beds and the limestone dikes. The minerals deposited from solution are of later origin than the limestone dikes. Fig. 16 shows in detail a small section of the tuff exposed on the side hill north of the Langley house. The chalcedony was deposited along a fault line developed after the intrusion of the limestone into the tuff. Fig. 17 is a photograph taken on the Searsville-La Honda road a quarter of a mile north of La Honda, and shows the tuff cut by limestone dikes and calcite veins.

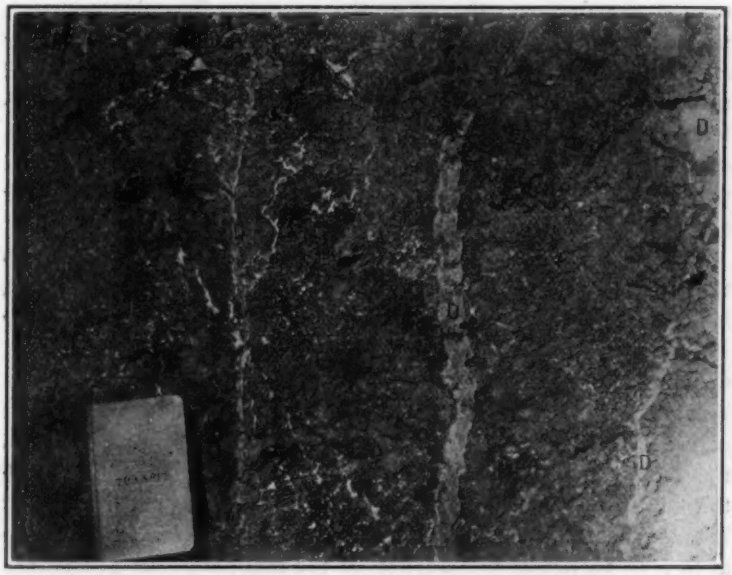

Fig 17. Vertical section along the Searsville-La Honda road one fourth mile north of La Honda, showing limestone dikes (D) and secondary calcite veins (V) in the diabase tuff. Photograph by Ralph Arnold.

The origin of the limestone dikes is easily accounted for when the relations of the containing and associated terranes is consid-

ered. The series of beds in which the dikes occur north of the Langley house have an upward sequence of sandstone, tuff, limy shales, and then alternating thick beds of tuff, comparatively thin beds of limestone and limy tuff, the whole capped by sandy tuff, above which are shale and sandstone beds (see Fig. 14.) Soon after the deposition of this series, and before the tuffs and limestones had become very coherent, diabase was intruded between the lower sandstone layer and the overlying tuffs. The intruded bed fractured the tuff along lines approximately perpendicular to the bedding planes of the series, and the unconsolidated ooze and limy tuff of the interbedded layers flowed into the fissures, thus forming the dikes.

The Diabase.

Studied in the field the diabase presents two facies. One will be termed the diabasic, the other the basaltic. The distinction is made purely on the physical appearance of the two. No great chemical difference exists, but the crystallization, color, texture and manner of weathering are so radically different that, while no differentiation is attempted on the map, a distinction is necessary in describing the rocks microscopically. Secondary dikes of small proportions were found in the diabasic type, and will be briefly described under that head.

The diabasic facies.—The diabasic type seems to be confined to the masses which make the north and east boundaries of the area between the south fork of Tunitas Creek on the north and Langley Hill on the south. In all cases it lies along the crest of the range, making the highest peaks and giving them a peculiar rounded outline that is readily distinguishable at a distance. The rock is well exposed near the summit of the ridge, on the road which crosses the range two and one-half miles south of Sierra Morena. Here the course of the dike is plainly marked by the large rounded boulders on the hillsides. The rocks weather in such a way here as to give particular prominence to the feldspars, thus giving the mass the appearance of a gabbro. The soil derived from its disintegration closely resembles granitic soil. It is made up of granular particles with a slight reddish cast, and varying in size from a diameter of one quarter to one-sixteenth of an inch.

Macroscopically the rock is a medium grained, light gray, crystalline aggregate, in which three components are very readily dis-

tinguishable. One, augite, is present in dark patches intruded by the others, and showing distinct glistening cleavages. Magnetite can be detected in large flat plates and smaller grains, dark and lustrous. Separated with a knife-blade, small portions can be picked up readily with a magnet. The most evident component is the feldspar. It occurs in long white rod-like crystals sometimes as much as two inches in length, giving a reticulated appearance to the mass; it is banded and contains inclusions of magnetite and augite. Fig. 18*b* is a photograph of the typical diabasic facies, being specimen No. 24, the analysis of which is given as I in a following paragraph.

Fresh specimens showing but slight kaolinization are readily obtained. Occasionally a crystal is seen to contain a few clear, glassy spots quite easily distinguishable with a hand lens. They are probably analcite.

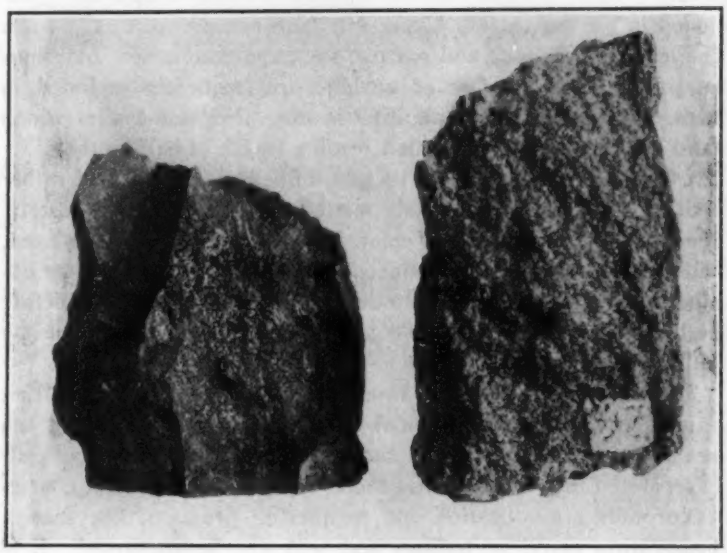

Fig. 18. (*a*) Showing the basaltic (specimen 38) and (*b*) true diabasic (specimen 24) facies of the diabase. Reduced one-half. Photograph by Ralph Arnold.

On the stage road from Redwood City to La Honda, at a point on the west side of the summit, about one-half mile from the Summit

House, the road cuts across the contact of the diabase with the lower Miocene sediments in a small canyon, so that a good cross section is exposed (see Fig. 2). The sediments here dip at an angle of sixty degrees south, twenty degrees west, and the diabase, which is of the coarse variety and rather badly weathered, follows the bedding planes. Within the diabase, running exactly parallel to the contact and dipping with the sediments, are a number of coarsely crystalline secondary dikes, varying in width from one inch to six inches and standing out hard and fresh in the darker decomposed diabase. Figure 2 is a photograph of this dike. The secondary dikes may be seen to the left of the man in the figure.

Macroscopically this rock is medium grained, light colored and with a rather mottled appearance, due to the uneven distribution of the more basic constituents. Augite, plagioclase and magnetite are the chief components. The augites are large and tend to segregate in spots, often with a poikilitic structure; the feldspars being included in the augites and giving a mottled appearance to the rock. The feldspars are long and narrow, somewhat kaolinized and show banding. Clear patches of analcite are frequently included in them. Magnetite is very plentiful in long irregular blades which stand out prominently and often reach a length of half an inch.

A few small cavities in the rocks are filled with a mass of rather flexible, fine, acicular crystals matted together indiscriminately. The crystals are usually light colored, although a few are discolored, evidently by weathering products. Such small amounts were obtained that it was impossible to determine them accurately. Before the blowpipe they are infusible and they are not acted upon by acids.

The basaltic facies.—It is thought best to treat all the fine-grained dark varieties which make up the remaining portion of the area under the head of basaltic facies. These in turn could be readily separated into at least two general types, differing in the coarseness of their crystallization and weathering products, but such a classification would be tedious and will not be attempted. It is necessary to state, however, that those portions of the area which are made up of smaller dikes are almost universally of a coarser texture than the larger masses and exhibit spheroidal weathering in a very striking way. Figure 19 illustrates a typical example of the spheroidal weathering of the medium grained diabase. The basaltic facies differ from the diabasic facies in that they are dark, show-

Fig. 19. Spheroidal weathering of the diabase exposed beside the Page Mill road, one-half mile east of the summit. × $\frac{1}{10}$. Photo. by R. Arnold.

ing the white feldspars but indistinctly, the predominating crystals being augites and olivines. The finer grained varieties make up the larger masses, such as the tuffs and some of the dikes of the Langley Hill-Mindego Hill igneous area, and are often amygdaloidal, weathering into a compact adobe soil. Amygdaloidal cavities of great size are frequently encountered. One cavity filled with quartz measured four inches along its greatest diameter. Calcite, chalcedony and serpentine fill the cavities in many instances, and on Bogess and Harrington Creeks diabase in place was found with its vesicles filled with petroleum. Perhaps the most interesting occurrence is the presence in many places of nests of glassy analcite crystals, filling the amygdaloidal cavities and joints and seams in the rock. Almost perfect icositetrahedrols were obtained. Qualitative tests showed the presence of Al, Na and SiO_2. The mineral is fusible before the blowpipe and soluble in hydrochloric acid, yielding no jelly, however; in this particular agreeing with the observation made by Lawson and Palache[1] on

[1] "The Berkeley Hills," *Bull. Dept. Geol. Univ. Cal.*, Vol. II, p. 418, Berkeley, 1902.

analcite from the andesites in the Berkeley Hills. At several points in the area small irregular aggregates, varying in size from one-tenth to one-half of an inch in diameter, made up of fan-shaped growths of slightly clouded, white crystals, were found in the weathered diabase. When tested before the blowpipe these crystals were found to be natrolite, and a thin section cut from one of the small bodies showed the angular centre area between the natrolite crystals to be filled with analcite (see Fig. 25). Calcite veins of considerable size were found in the mass in some places.

Macroscopically the rock is fine grained and dark. Augite and olivine crystal are readily detected in most specimens, sometimes in crystals large enough to be porphyritic. Plagioclase feldspar and magnetite are also present, and pyrite has been found in a few places. The augite is dark and lustrous and usually quite fresh. The olivine, however, is generally somewhat weathered to serpentine, which often fills the crystal cavity completely and gives the rock a greenish tint. Another weathering product of the olivine was found quite plentifully in thin scales of light brown color. Chemical tests showed the presence of Na, Ca, Fe and Mg. The mineral is hydrous and infusible. Treated with hydrochloric acid, it becomes lighter in color and gives up its iron. These, together with its optical properties, which will be mentioned, make it possible that it is the mineral described by Lawson[1] as iddingsite. The feldspars in this facies are almost universally microlitic. An occasional phenocryst is seen. Magnetite is present in small grains, barely visible to the unaided eye. The basaltic facies usually has a very distinct, coarse, conchoidal fracture. Figure 18*a* is a photograph of specimen No. 38, a piece of the typical basaltic facies, the analysis of which is given as II on a following page.

Microscopic Petrography.

The petrographic discussion contained herein is based upon the study of about one hundred and thirty slides, cut from the rocks collected over the diabase area and examined under the microscope. In thin section the eruptive presents two facies. Both are holocrystalline and contain about the same minerals, but the one presents a rather granular structure under the microscope, just as it does in the hand specimen; the other a finely crystalline, aphanitic

[1] "The Geology of Carmelo Bay," *Bull. Dept. Geol. Univ. Cal.*, Vol. I, p. 31.

structure with smaller individuals, yet of nearly the same chemical composition. While no separation of the two has been attempted in mapping in the field, they will be treated under separate heads in dealing with their microscopic character. In describing their field relations the first has been called the diabasic, the latter the basaltic facies. It is not intended that these terms shall be used to designate two distinct series of rocks, but rather in the sense of a convenient classification of two facies of the same magma.

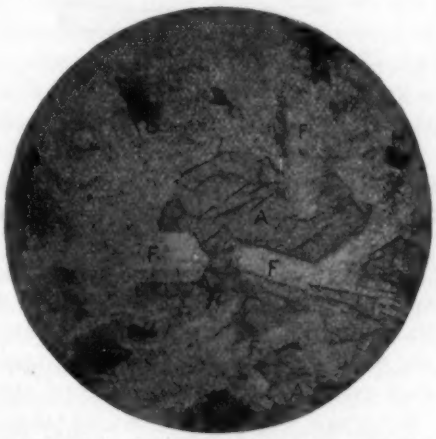

Fig. 20. Thin section of the diabase facies (specimen 24), showing the typical diabase structure. (A), augite; (F), feldspar; (M), magnetite. × 20. Photograph by Ralph Arnold.

The Diabasic Facies.

Considering the general tendency of the eruptive to disintegrate, the diabasic type is usually remarkably fresh and clear in thin sections. The slides show the following principal constituents, given in the order of their crystallization: magnetite, ilmenite, apatite, olivine, feldspar, augite and analcite. The last is never present as an original constituent, so far as could be determined, but is certainly in many cases, and probably in all cases, a secondary product. Of the secondary minerals, serpentine, chlorite, iron ores, calcite and natrolite have been noted.

Plagioclase.—The feldspar is generally present in the diabasic facies in rather stout, lath-shaped forms with an average length of two millimeters, twinned according to the Albite and Carlsbad laws

Fig. 21. Twinned crystal of labradorite, showing cleavage. × 60.

(see Fig. 21). Of the two, the Albite twinning predominates and is usually polysynthetic, and occasionally combined with the Pericline. Crystals cut parallel to the composition plane and showing tabular forms are not infrequent, and in many cases show zonal structure and wavy extinction, indicating a centre more basic than the periphery. Extinction angles were carefully taken and indicate plagioclases of about the order of labradorite with a formula of mixture about Ab_3An_4.

Decomposition of the feldspars has gone on to a great extent in portions of the mass. Comparatively fresh sections are obtainable, however, in places. Kaolinization is very common in all sections. The most characteristic alteration, however, seems to be that which results in the formation of analcite within the feldspar. Nor does it seem that any one law of decomposition applies to all the cases seen. In one instance a mere patch of an isotropic, clear glassy mineral is found in the centre of a plagioclase. In another the crystal form of the feldspar appears to be filled with the product, except, perhaps, a small fresh patch of the original mineral left in the centre, in just such a position as the analcite held in the first case cited. Occasionally the whole crystal is replaced by the analcite. In the slides examined there seems to be much evidence that the analcite is an alteration product (in these instances) of the feldspars themselves. The problem of the percentage of soda required for the

formation of analcite will be discussed under the head of "Chemical Characters."

Lenses of high powers reveal the presence in the feldspars of many dust-like particles, the nature of which is unknown. Usually they are without definite arrangement. Inclusions of gas bubbles, patches of augite, magnetite, and also serpentine and chlorite are noted.

Augite.—Augite is very plentiful in the diabasic facies of the rock, and is usually allotriomorphic with respect to the feldspars. It is of a pale brown color with a tinge of red, probably due to a small percentage of titanium—a supposition which the rock analysis appears to verify. Its pleochroism is faint, changing the shade and not the color. Extinction angles as high as 53° were noted, and zoned crystals with undulatory extinction were occasionally seen. Twinning is not uncommon. Cleavage cracks are very distinct, and the intersecting cleavage lines parallel to the prism of 87° 6′ are frequently observed. The augite is remarkably fresh and clear in this rock, having withstood the effects of weathering better than the feldspars. Smaller crystals of augite, occasionally included in the larger phenocrysts, are often almost entirely decomposed into what appears to be a yellowish-brown chlorite, the coloration being due to the iron ores present. Frequent irregular patches of gas and fluid inclusions occur in the phenocrysts, sometimes long and rope-like, and often clustered around smaller included grains of augite. Irregular inclusions of feldspar are often found and are generally much kaolinized. Magnetite and its decomposition products are also present in the phenocrysts.

Olivine.—Olivine is not abundant in the slides of the diabasic facies. It would have been possible, however, to so choose the sections as to show considerable of this mineral, as its occurrence seems to be in occasional local patches and segregations. It is present, however, in very small quantity in the typical slides, usually in minute clear patches, making up the centre of a mass of brownish decomposition material, badly discolored by iron and showing no characteristic optical properties. Its crystal form, where disintegration is complete, suggests its origin from olivine. In rare instances, too, this secondary decomposition mass assumes a fibrous structure, strong pleochroism and strong double refraction with bright red and green polarization colors, suggesting iddingsite.[1]

[1] "The Berkeley Hills," by A. C. Lawson and Chas. Palache, *Bull. Dept Geol. Univ. Cal.*, Vol. II, No. 12, p. 430, Berkeley, 1902.

Other Minerals.—Magnetite and some ilmenite are present in the diabase as grains and irregular masses. Grouping is occasionally seen, but for the most part both of these minerals are scattered through the mass without definite position.

Apatite is sparingly present in its usual characteristic clear, long, slender prisms, included by the other constituents.

Of the secondary products analcite is by far the most important. It occurs chiefly in the feldspars in the diabasic facies. In no instance could it be shown that it is other than a secondary product, nor does it indicate an origin other than of an alteration product of the feldspars. Treated with hydrochloric acid it is soluble, but forms no jelly.

Fig. 22. Section of secondary dike. (A), analcite; (P), augite; (F), feldspar. × 30.

The Secondary Dikes.—In thin sections the rocks of the secondary dikes contain apatite, magnetite, augite, sphene, feldspar, pyrite, analcite and natrolites (see Fig. 22). The sections are particularly clear and fresh.

The feldspars are plagioclases with the composition of labradorite. They are broadly lath-shaped and show Albite twinning. Wavy extinction with a basic interior and more acid periphery is common

Kaolinization is somewhat advanced; dust-like inclusions, together with augite and magnetite, are frequent.

The augites are of the pale purplish-brown variety with slight pleochroism. They make up an unusually small percentage of the rock, however. Basal sections show wavy extinction. Both idiomorphic and allotriomorphic crystals are present. Cleavage is distinct and relief high. Inclusions of feldspar and magnetite are numerous and decomposition very slight.

Magnetite is present in unusual quantities and in very striking, long, slender rods, as well as in its common tabular forms. A few crystals of pyrite were noted, also a wedge-shaped crystal of sphene.

Analcite and natrolite are present in these sections in greater quantity than in those of any other portion of the mass.

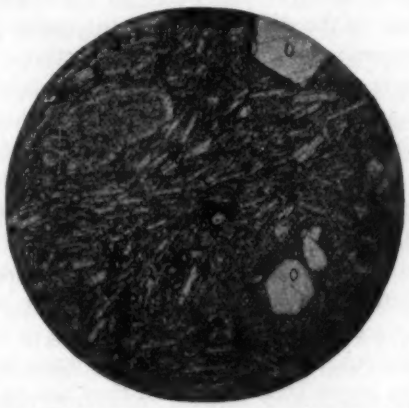

Fig. 23. Section of the basaltic facies (specimen 38), showing basaltic and flow structure. (O), olivine; (O′), olivine weathering to iddingsite; (F), feldspar crystal with etched edges; (A), augite. × 20. Photograph by Ralph Arnold.

The Basaltic Facies.

In thin section the basaltic facies of the igneous mass presents a more difficult problem than the diabasic type, because it is universally more weathered. The typical section shows a few phenocrysts of olivine and augite in a fine-grained ground mass of lath-shaped feldspars, microscopic augites and olivines, ilmenite, magnetite, and the secondary products—calcite, serpentine, chlorite, iddingsite, iron oxides, natrolite and analcite.

Feldspar.—The feldspars are in two general forms—typical lath-shaped crystals and broader tabular plates with wavy extinction or zonal structure and, usually, an abundance of inclusions. The lath-shaped crystals predominate. As far as it was possible to determine them, both seem to be of the order of labradorite and exhibit the same extinction angles that were characteristic of the plagioclases of the diabasic type. Individual crystals are seldom over one millimetre in length. Twinning is usually polysynthetic according to the Albite law, although Carlsbad twins are frequently noted. Flow structure is often beautifully shown by the arrangements of the lath-shaped microlites in regular courses between the larger crystals of augite or olivine (see Fig. 23). Not infrequently the ophitic structure of the typical diabase is seen, the feldspars radiating, in all cases noted, around the larger crystals of olivine. This is particularly true of the slides cut from the rocks of the narrow dikes. In numerous cases, especially in sections showing flow structure, feldspars are bent and broken and displaced. In many slides the ground mass is badly decomposed and shows practically no optical phenomena, except such as is shown by the feldspar microlites which, in these sections, are so badly etched along the crystallographic outlines that they present rough, saw-like edges (see F, Fig. 23). Feldspars differing from the general type are occasionally found in the slides. Slides from one exposure show feldspars which at first glance might be mistaken for orthoclases, so clear and regular are they and free from banding or twinning. Inclusions are numerous, however, and a closer examination of their optical properties leaves little doubt that they belong to the plagioclases. There is an unusual amount of analcite in these slides, which suggests very strongly that the feldspars may contain a larger percentage of soda. Again some sections show feldspars, the order of whose interference colors borders closely on nepheline, and one slide shows a number of crystals whose optical properties would tend to class them as melelites. In view of these resemblances, tests were made upon the thin sections to determine physically whether the optical properties were true indicators. The results, however, left no doubt that the crystals were simply feldspar. Crystals were also found in these slides, portions of which gave the normal optical phenomena of the feldspars common to the rock. Low order interference colors are frequently met with in the more weathered slides, but in no case could nepheline be positively detected.

The matter of the presence or absence of the nepheline was made the object of particularly careful search, as its presence, if established, would materially assist in accounting for the soda necessary to the formation of analcite, as has been observed by Fairbanks in dealing with a very similar rock in San Luis Obispo County.[1] As shown above, however, it is very doubtful whether any nepheline occurs in either facies of the diabase of the area here under discussion.

Pyroxene.—The pyroxenic constituent is usually augite, but enstatite is occasionally noted. The augite occurs, in general, in two ages—a more or less porphyritic series which are occasionally idiomorphic and frequently absent entirely in the slides, and a series of small allotriomorphic grains filling the interstices between the feldspars and olivines of the ground mass. Augites of this latter type are seldom over five-hundredths of one millimetre in diameter, and seem to be identical in composition and optical phenomena with the porphyritic type. No grouping of either type could be detected, the only instance of a perceptible order of arrangement being found in the slides from one small area on Harrington Creek, where porphyritic augites with distinct micropoikilitic structure were observed. The included crystals were particularly fresh plagioclases, which made up about fifty per cent. of the cross section of the pyroxene host. The phenocrysts seldom attained a large size in this facies and were usually broken by mechanical strains or rounded and etched by chemical action, However, elongated crystals with approximately idiomorphic outlines were not uncommon. The augite is of the same pale brown to pinkish tint noted in the diabasic facies. Like it, too, it is but slightly pleochroic, except for some few scattered individuals whose pleochroism is somewhat marked. Polarization colors are very brilliant. Twinning according to the augite law is not uncommon. Only simple twins were noted. Inclusions of glass, gas bubbles and magnetite were noted in the porphyritic crystals.

Enstatite is found in a few instances in irregular plates showing low interference colors. The crystals were in no case large, two-tenths of one millimetre being the greatest diameter measured. The surfaces of the crystals were distinctly pitted, but no distinct

[1] "Analcite Diabase," by H. W. Fairbanks, *Bull. Dept. Geol. Univ. Cal.*, Vol. I, pp. 273–300, Berkeley, 1895.

cleavage was observed. Irregular patches of the enstatite were found included in the feldspars.

On the whole the pyroxenes are remarkably fresh. Many slides show absolutely no decomposition products even where the feldspars are badly weathered. In a few instances slight chloritization was noted, that being practically the only indication of decomposition.

Olivine.—The olivine, like the augite, is present in two generations, porphyritic and microlitic. The porphyritic crystals are usually idiomorphic and are among the oldest segregations of the magma. They are usually much fractured and jointed, and rounded or embayed by the corrosive action of the magma. Usually disintegration has gone on to such an extent that only the crystal form remains, filled with the secondary products. Where the original olivine remains it is clear and colorless, with strong double refraction and high relief. It usually includes much magnetite in small grains, some glass and dust particles.

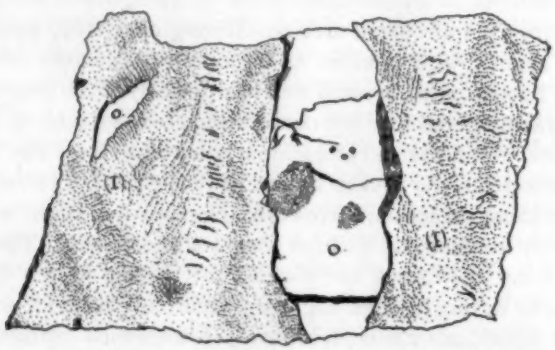

Fig. 24. Phenocryst of olivine (O) weathering to iddingsite (I). × 60.

The most common product of decomposition is serpentine, which frequently shows its fibrous character. Alteration begins along the cracks, gradually working inward from them until the crystal is divided into a number of irregular rounded patches of clear olivine separated by fibrous serpentine, the whole making up the complete form of the original crystal. Perhaps fifty per cent. of the phenocrysts studied were completely replaced in this way, the remainder showing various stages of such decomposition or alteration in like manner to the mineral, which is probably iddingsite (see Fig. 24

and O[1], Fig. 23). It shows high polarization colors and is strongly pleochroic in the green shades, the greatest absorption being parallel to the fibres. It agrees strongly with the mineral described by Iddings[1] from Nevada and afterwards named iddingsite by Lawson. A small amount of chlorite was noted. Calcite is quite abundant in the more weathered portions of the rock. It is usually found filling seams, joints and amygdular cavities.

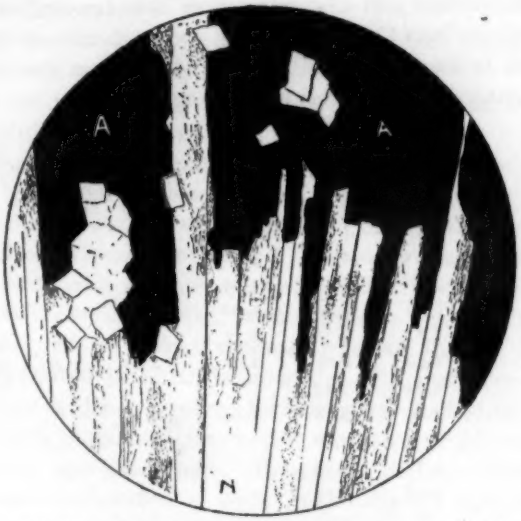

Fig. 25. Natrolite (N) and analcite (A) between crossed nicols. × 30.

Analcite.—The most striking product of decomposition is analcite. Its occurrence in the field has been described. In certain areas it is quite plentiful. In thin section it is often found associated with natrolite, fibrous aggregates of which it frequently includes (see Fig. 25). It is isotropic, occasionally showing optical anomalies. It has been observed to occur in five general ways: 1. In irregular patches in the centre of crystals of plagioclase. 2. In a form suggesting a decomposition product of the plagioclases, advancing in irregular lines from the crystal edges inward. 3. Completely filling what seems to have been the rectangular outline of a plagioclase crystal. 4. In irregular patches filling the angular

[1] "Geology of the Eureka District, Nevada," by Arnold Hague, Mon. XX, *U. S. G. S.*, Appendix B, pp. 388–390, Washington, 1892.

spaces between crystals of feldspar. 5. In large irregular patches sometimes two and a half millimetres in diameter, filled with a confusion of microlites of some indeterminable mineral.

Chemical Characters and Analyses.

The writers are indebted to the United States Geological Survey for the analyses (I and II) of the two typical facies. For the purpose of comparison and discussion there have been added analyses of the analcite from Cuyamas [1] (III), the teschenite diabase (IV), plagioclase feldspar (VI) and analcite (VII) from Point Sal,[2] and a typical analysis of labradorite from Dana (V).[3]

	I.	II.	III.	IV.	V.	VI.	VII.
SiO_2	50.12	49.60	50.55	49.61	56.0	52.72	54.40
Al_2O_3	18.52	16.56	20.48	19.18	27.5	30.46	23.04
Fe_2O_3	2.47	4.28	2.66	2.12	0.7		
FeO	4.11	4.44	4.02	5.01			
MgO	2.68	5.38	4.24	4.94	0.1		
CaO	8.99	9.22	7.30	10.05	10.1	11.01	0.21
Na_2O	5.22	3.31	8.37	5.62	5.0	3.70	13.33
K_2O	1.46	1.25	2.27	1.04	0.4	0.42	0.19
H_2O	1.64	1.44					
H_2O	3.09	2.58	0.44	Ig 3.55		1.44	8.46
TiO_2	1.33	1.86					
P_2O_5	0.18	0.30		0.27			
So_3	0.08	0.17		tr.			
Cr_2O_3	tr.	0.03					
NiO	none	none					
MnO	tr.	0.08					
BaO	0.02	0.06					
	99.91	100.55	100.33	101.39	99.8	99.75	99.63
Sp. Gr.	2.732	2.825		2.782			

(I) Diabase (typical diabasic facies), from one mile north of Bella Vista ranch houses, San Mateo County, California. Specimen No. 24. E. T. Allen, Analyst. (U. S. Geological Survey.)

(II) Diabase (typical basaltic facies), from Mindego Hill, San

[1] "Analcite Diabase," by H. W. Fairbanks, *Bull. Dept. Geol. Univ. Cal.*, Vol. I, p. 293, Berkeley, 1895.

[2] "The Geology of Point Sal," by H. W. Fairbanks, *Bull. Dept. Geol. Univ. Cal.*, Vol. II, pp. 1-92, Berkeley, 1896.

[3] *System of Mineralogy*, by J. D. Dana. Sixth edition.

Mateo County, California. E. T. Allen, Analyst. (U. S. Geological Survey.)

(III) Analcite diabase from Cuyamas, San Luis Obispo County, California. V. Lenher, Analyst. (Fairbanks.)

(IV) Augite-teschenite from Point Sal. Santa Barbara County, California. (Fairbanks.)

(V) Labradorite, typical analysis, Dana, System of Mineralogy, Sixth Edition, p. 337.

(VI) Feldspar from Augite-teschenite, Point Sal, Santa Barbara County, California. (Fairbanks.)

(VII) Analcite from Augite-teschenite, Point Sal, Santa Barbara County, California. (Fairbanks.)

The close relation between the two facies, as far as chemical composition is concerned, is very evident. A striking similarity exists also between them and the two analyses of very similar rocks from San Luis Obispo County, described by Fairbanks as analcite diabase and augite-teschenite. Hand specimens and a few slides of these latter rocks which were studied for comparison tend to emphasize this similarity, and to make it reasonably certain that the rocks are very closely related in all their properties. In that connection it seems that the evidence gathered by Fairbanks,[1] in dealing with the probable origin of the analcite in rocks which are of this same type, is particularly applicable here. Fairbanks' analyses both show a slightly greater percentage of soda. Optically his feldspars agree with those encountered here. Chemically they are very like the typical labradorite of Dana (V). Nothing new beyond the data given by Dr. Fairbanks in his discussions was discovered in the examination of the rocks herein described. The conclusions reached by that author, however, are but vaguely substantiated. The presence of nepheline, at some time in the history of the diabase, has not been proven. Aside from the fact that analcite is present, and that the soda necessary to permit of its formation could not have come from a concentration of that element from the feldspars alone, to the extent that the entire rock should show a percentage of soda equal to that of labradorite, there is nothing to suggest the presence of nepheline at any time. The presence of the analcite chiefly within the feldspars themselves would point

[1] "Geology of Point Sal," *Bull. Dept. Geol. Univ. Cal.*, Vol. II, p. 30; and "Analcite Diabase," *Bull. Dept. Geol. Univ. Cal.*, Vol. I, p. 293, Berkeley, 1896.

to its origin as a product of their partial disintegration; while its presence filling angular cavities between crystals of feldspar would indicate that it might have replaced whatever mineral originally filled that area, for it is hardly possible to conceive of that area being left vacant after the magma had cooled and crystallized. Yet, were it conceded that nepheline did occupy these areas, it would still be impossible to believe that it could furnish enough soda for the patches included in the feldspars. This problem remains unsolved.

Titanium is present in some quantity, as shown by the analyses of the rocks discussed in this paper. None, however, is listed from those studied by Fairbanks. It is possible that no determination of that element was attempted by him. The presence of such an amount of titanium, however, suggests that the augite, which is of the pinkish variety both in this occurrence and in those described by Fairbanks, carries some titanium. Ilmenite, which is sparingly present, probably accounts for the remainder.

Summary and Conclusion.

Within an area of about three hundred square miles, most of which is shown on the accompanying map, there are exposed about thirty-five square miles of diabase in the form of tuffs, dikes and intrusive sheets. The tuffs are interbedded with lower Miocene strata and overlain by probable middle Miocene shales. The basaltic facies of the diabase is partly contemporaneous with the tuffs and partly of later origin, while the diabase facies is intruded into the tuffs and middle Miocene beds. The igneous rocks under discussion are therefore of lower and middle Miocene ages.

The tuffs are composed of fragments of the basaltic facies, generally angular, but sometimes water-worn. The tuffs are interbedded with limestones, sandstones and shales. Intrusions of limestone derived from the interbedded limy layers have been forced into fissures in the tuff.

Petrographically the diabase is of two general types. One is a light colored, granular rock which is found along the crest of the range north of Langley Hill. The other is a darker, fine grained, basaltic type with occasional phenocrysts of olivine and augite; the latter type makes up the remaining area.

The rock is uniform in its chemical composition, which approxi-

mates that of the typical diabase. The percentages of soda and titanium are large. The former is probably due to the amount of analcite present, and the latter to the character of the augite.

The rocks are closely allied in character and age to those described by Fairbanks from San Luis Obispo and Santa Barbara Counties under the name of augite-teschenite. While analcite is present in considerable quantity and is one of the most interesting features of the rocks, it is also found in basic rocks in several instances on the Pacific Coast, and its presence, taken in connection with other properties of the rock, is not regarded as sufficient to warrant the substitution of the name augite-teschenite for that of diabase. That name has, therefore, not been retained by the writers.

Stated Meeting, February 19, 1904.

President SMITH in the Chair.

An invitation was received from the University of Wisconsin to send a representative to the Jubilee of the University, to be held at Madison, commencing June 5, 1904, and the President was, on motion, directed to appoint a delegate.

The donations to the Library were laid on the table and thanks were ordered for them.

The following papers were read:

"Present Aspects and Future Prospects of Forestry in Pennsylvania," by Prof. Joseph T. Rothrock. Discussed by Prof. Haupt, Mr. Stuart Wood, Mr. Richard Wood, Dr. Marshall and Mr. Goodwin.

"Views of Old Philadelphia," by Mr. Julius F. Sachse. Discussed by Mr. Goodwin, Mr. Stuart Wood, Mr. Harrison and Mr. Richard Wood.

"A Method of Controlling the Floods of the Mississippi River," by Prof. Lewis M. Haupt. (See page 71.)

Stated Meeting, March 4, 1904.

President SMITH in the Chair.

A communication was received from the Committee of Organization of the Fourteenth Congrès Internationale des Orientalistes, announcing that the Congress will be held in Algiers, in Easter week in 1905, and inviting the Society to send delegates. On motion, the President was authorized to appoint delegates.

A list of donations to the Library was laid on the table and thanks were ordered for them.

The following papers were read:

"Literary Remuneration in the Eighteenth and Nineteenth Centuries," by Prof. Albert H. Smyth.

"Uranium Minerals and their Photographic Action," by Prof. George F. Barker.

"The Native Tribes of Victoria: Their Languages and Customs," by R. H. Mathews.

THE NATIVE TRIBES OF VICTORIA: THEIR LANGUAGES AND CUSTOMS.

BY R. H. MATHEWS, L.S.

(*Read March 4, 1904.*)

SYNOPSIS.—Prefatory. Orthography. Dhauhurtwūrru Language and Vocabulary. Initiation Ceremonies. Folklore. Sociology.

The object of the present short paper is to supply some missing links in the literature of the aborigines of Victoria. For a number of years past I have devoted a portion of the leisure of a busy professional man to taking special journeys among the remnants of the Victorian tribes, for the purpose of adding to our knowledge of their languages, ceremonies, sociology and customs generally. When first entering upon this congenial task I found that little or

nothing had been done to record and preserve the native languages of Victoria, and also that the rites and customs of the people had not received the attention which their importance deserved.

Perhaps it should be mentioned that in 1898 I contributed to the Anthropological Society at Washington a paper dealing with the initiation ceremonies and divisional systems of the Victorian aborigines.[1] In 1902 I read another paper on the aboriginal languages of Victoria before the Royal Society of New South Wales.[2] On the present occasion it is intended to supply further information not included in my former memoirs. The whole of this article has been prepared by me from notes written down by myself from the lips of the aboriginal speakers. When the difficulties encountered in obtaining such particulars from an uncultivated race are taken into consideration, I feel sure that all necessary allowances will be made for any imperfections of my work.

In all the aboriginal languages of Victoria the pronouns and pronominal affixes have two forms in the first person of the dual and plural—one of which includes, and the other excludes, the party spoken to. Again, inflection for person and number is not confined to the pronouns and verbs, but extends to many of the nouns, prepositions, adverbs and interjections. I was the first author to report, in any of the Australian languages, the important grammatical forms referred to in this paragraph.[3]

The items of folklore show the proclivity of the native mind to account for any specialties of animal structure, or remarkable formations in hills, trees, lakes and the like. Under the head of "Sociology," although the names of the phratries have been known for some time, yet many new and important details have been gathered and reported in this article.

The natives of the southwestern portion of Victoria have a habit of distinguishing the neighboring tribes by means of the second personal pronoun, "thou," of their respective dialects. For example, the Dhauhurtwūrru are known as the *Ngutuk* people, the Būngandity as the *Nguro* people, and so on. A more widely prevalent practice is to name the dialect of a tribe by the lip, which is symbolical of speech. For this purpose they suffix to the name of the tribe the native word, wūrru, lip; or its possessive form, wūrrung,

[1] *American Anthropologist*, Vol. xi, pp. 325–343, with map of Victoria.
[2] *Journ. Roy. Soc. N. S. Wales*, Vol. xxxvi, pp. 71–106.
[3] *Ibid.*, Vol. xxxv, p. 127.

lip of (someone). In other districts the equivalent of our negative adverb, "No," is used, with the suffix *wūrru*, as, Woi-wūrru, meaning the No-lip, or Woi-speaking, people.

Orthography.

Eighteen letters of the English alphabet are sounded, comprising thirteen consonants—b, d, g, h, k, l, m, n, p, r, t, w, y—and five vowels—a, e, i, o, u.

The system of orthoepy adopted is that recommended by the Royal Geographical Society, London, but a few additional rules of spelling have been introduced by me, to meet the requirements of the Australian pronunciation.

As far as possible, vowels are unmarked, but in some instances the long sound of *a*, *e*, *o* and *u* are indicated thus, *ā*, *ē*, *ō*, *ū*. In a few cases, to prevent ambiguity, the short sound of *u* has been marked thus, *ŭ*.

It is frequently difficult to distinguish between the short sound of *a* and that of *u*. A thick sound of *i* is occasionally met with, which closely resembles the short sound of *u* or *a*.

G is hard in all cases. *W* always commences a syllable or word.

Ng at the *beginning* of a word or syllable has a peculiar nasal sound, which can be obtained by adding together the two English words "hang up," making "hangup"; then assume this divided into two syllables, thus, "ha-ngup." By pronouncing this so that the two syllables melt into each other, the *ng* of "-ngup" will represent the aboriginal sound. At the *end* of a syllable, *ng* has the sound of *ng* in "sing."

At the beginning of a word or syllable, the sound of the Spanish ñ is given by *ny*, but when terminating a word, the Spanish letter is used.

Dh is pronounced nearly as *th* in "that," with a slight sound of *d* preceding it. *Nh* has also nearly the sound of *th* in "that," but with an initial sound of the *n*.

A final *h* is guttural, resembling *ch* in the German word joch.

T is interchangeable with *d*, *p* with *b*, and *g* with *k*.

Ty and *dy* at the commencement of a word or syllable have nearly the sound of *j* or *ch*, thus, tyu, in the name of Tyu-ron, closely resembles *chu* or *ju*. But at the end of a word or syllable *ty* or *dy* is sounded as one letter; thus, *raty*, the last syllable of

barraty, can be pronounced exactly by assuming *e* to be added to the *y*, making it rat-ye. Then commence articulating the word, including the *y*, but stopping short without sounding the added *e*.

The Dhauhurtwūrru Grammar.

The Dhauhurtwūrru language is spoken in the country about Portland and Lake Condah, in the State of Victoria, but it is representative of the native speech from the Glenelg to the Gellibrand river, and reaching inland about fifty miles or more.

ARTICLES.

The place of the English article is supplied by the various forms of the demonstratives, representing "this" and "that."

NOUNS.

Nouns have number, gender and case.

Number.—Mār, a man. Mārara, a couple of men. Māraban, several men.

Gender.—Sex in the human family is distinguished by different words, as, mār, a man; dhunnumbur, a woman. Wurran, a boy; barraty, a girl.

Among animals gender is denoted by the addition of words signifying "male" and "female," as, warrun mamung, a male bandicoot; warrun ngerang, a female bandicoot. The females of certain animals have a name which distinguishes them without stating the sex, as, ngerangyer, a female dog; murrin, a female kangaroo. The corresponding male names are gal and gorañ. Many of the male animals likewise have a distinguishing name.

Case.—The cases are indicated by inflections, the following being the principal:

Nominative: This case merely names the subject at rest, as, gal, a dog; kunna, a yamstick; mār, a man; dher, a spear. Mutyir or kurkin, a tomahawk.

Causative: This represents the subject acting, as, mārra guramuk burtan, a man an opossum killed; dhunnumburra gal yilpan, a woman a dog flogged; galla guramuk būndan, a dog an opossum bit.

Instrumental: This case takes the same affix as the causative, as, mārra kalngun maiangan dherra, a man my dog speared (or pierced)

with a spear. Sometimes the first affix is omitted in such a sentence as this.

Genitive: A peculiarity of the genitive case, which I was the first author to report in Australian languages,[1] is that the property and the possessor each take an affix, but the former affix differs from the latter—marngat lettalettimyung, a man's boomerang; dhunnumburngat kannanyūng, a woman's yamstick; wurranngat kurkinyung, a boy's tomahawk.

Every object or article over which ownership can be exerted is subject to inflection[2] for person and number, as, kurkinngun, my tomahawk; kurkinngu, thy tomahawk; kurkinung, his tomahawk; and so on through the dual and plural, which also contain "inclusive" and "exclusive" forms in the first person.

Accusative: This case is the same as the nominative.

The other cases will be passed over.

ADJECTIVES.

Adjectives follow the nouns which they qualify, and are subject to similar declensions for number and case:

Nominative: Mār muryarrung, a man large. Gal lēnggin, a dog large. Dhunnumbur dhugai-muruk, a little woman.

It is not thought necessary to illustrate the other cases.

Comparison: Din ngutyung—dinnung ngummindyar, this is good—that is bad. Din kurpung kurpung, this is the best.

In the declensions of all the cases of nouns, and of their qualifying adjectives, there are modifications in the affixes, depending upon the termination of the word declined. Sometimes the affix of the noun is omitted, sometimes that of the adjective; this rather being regulated by the euphony of the sentence.

PRONOUNS.

Pronouns are inflected for number, person and case, and contain two forms of the first person of the dual and plural, marked "inclusive" and "exclusive," respectively.

[1] "The Gundungurra Language," PROC. AMER. PHILOS. SOC., Philadelphia, Vol. xl, p. 143.

[2] "The Thoorga Language," *Queensland Geographical Journal*, Vol. xvii, p. 53.

The following is a full table of the nominative pronouns:

Singular....	1st Person I		Ngutthuk
	2d " ..... Thou		Ngutuk
	3d " ..... He		Nung
Dual.....	1st Person.....	We, inclusive	Ngutthungul
		We, exclusive	Ngutthungullin
	2d "	You	Ngutuwal
	3d "	They	Dilakal
Plural.....	1st Person.....	We, inclusive	Ngutthungan
		We, exclusive	Ngutthungannin
	2d "	You	Ngutuwan
	3d "	They	Dilakanda

There is a sort of trial number, which is formed by the addition of the word *balinia* to the plural, as, Ngutthangan balinia, we three, and so on for the remaining numbers. I am inclined to believe, however, that this added word merely serves the purpose of a numeral, and is copied from the Wuddyāwūrru tribes on the east, and the Tyattyalli on the north, among whom I reported a trial number last year.[1]

The following are examples in the singular number of the possessive case:

Singular....	1st Person..... Mine		Ngutthungat
	2d " ..... Thine		Ngutungat
	3d " ..... His		Nungat

And so on through the remaining numbers.

The full forms of the pronouns given above are mainly used in replying to a question. In ordinary conversation the natives use the pronominal affixes illustrated under the head of "Verbs."

The accusative pronouns, me, thee, him, etc., are not found separately, like the nominative and possessive, but consist wholly of the pronominal suffixes to verbs, nouns or other parts of speech, as in the following example:

1st Person.....	(Some one)	beats me	Burtangun
2d "	"	beats thee	Burtangu
3d "	"	beats him	Burtanung

And so on through all the numbers. See also the example under the heading "Prepositions."

Demonstratives: The demonstratives in this language, by the

[1] *Journ. Roy. Soc. N. S. Wales*, Vol. xxxvi, pp. 77–86.

combination of simple root-words, can be made to indicate position, distance, direction, number, person, movement, etc. Want of space precludes more than this brief reference to them at present.

Interrogatives: Who, winya. What, nganya. How many, nummia.

VERBS.

Verbs have the same numbers and persons as the pronouns, and also the "inclusive" and "exclusive" forms. The principal moods are the indicative, imperative and conditional. Person and number are indicated by pronominal affixes to the root of the verb, as in my Būngandity grammar.[1] In the following conjugation of the verb, burte, "to beat or kill," the present tense is given in full, but the singular number of the past and future is considered sufficient.

Indicative Mood—Present Tense.

Singular....	1st Person.....	I beat	Burtu
	2d "	Thou beatest	Burtangin
	3d "	He beats	Burta
Dual.....	1st Person.....	We, incl., beat	Burtangul
		We, excl., beat	Burtangullin
	2d "	You beat	Burtawul
	3d "	They beat	Burtakal
Plural.....	1st Person.....	We, incl., beat	Burtangan
		We, excl., beat	Burtangannin
	2d "	You beat	Burtawan
	3d "	They beat	Burtakanda

Past Tense.

Singular	1st Person.....	I beat	Burtanu
	2d "	Thou beatest	Burtanyin
	3d "	He beat	Burtan

Future Tense.

Singular	1st Person.....	I shall beat	Burtugu
	2d "	Thou shalt beat	Burtuhu
	3d "	He shall beat	Burtuk

Imperative: Beat, Burtē.

[1] "Language of the Būngandity Tribe, South Australia," *Journ. Roy. Soc. N. S. Wales*, Vol. xxxvii, pp. 59–75.

There are conditional, reflexive and reciprocal moods, similar in principle to those shown in my Kamilaroi grammar.[1] There are also modifications of the verbal suffixes of the past tense to indicate the immediate past, the recent past, and the remote past. Similar modifications exist for the proximate, or more or less distant future. There are likewise forms of the verb to express repetition or continuance of the act described, and many other complexities, which need not be detailed in the present brief paper.

ADVERBS.

Following are a few examples in this part of speech:

Yes, ko. No, bangat. To-day, thinggatbe. Yesterday, ngagat. To-morrow, tungatti. By and by, kalu. Recently, wuluba. Long ago, mulkaiu. All the time (doing something), girtnabe. All the time (resting), girtitbe. Where, wunda. Where art thou, wundayin. Where are you two, wundawar. Where are you all, wundawan.

PREPOSITIONS.

Here, dinnu. There, dinnunung. These, with numerous modifications, are also used as demonstratives.

In front, gullingat. Behind, wurtgat. On the right, dumbitgat. On the left, warumgat. Inside, gunni. Outside, gunna. Between, bukkargat. This side, yukkai-gatthung. Other side, kunninung. Down, wēnyu. Up, gunnu. Underneath, wenyanu. Through, yunyin.

Many prepositions admit of inflection for person and number, as in my "Thurrawal Language":[2]

Singular	1st Person.....	Behind me	Wurtganhūn
	2d "	Behind thee	Wurtganhu
	3d "	Behind him	Wurtganhung

And so on through the remaining numbers and persons.

NUMERALS.

One, kaiappa. Two, bulattya. Several, bōrtung.

[1] *Journ Anthrop. Inst.*, July–December, 1903.
[2] *Journ. Roy. Soc. N. S. Wales*, Vol. xxxv, p. 148.

Vocabulary.

This vocabulary contains about 260 of the most commonly-used words in the Dhauhurtwūrru language, every word having been noted down by myself from old men and women in the native camps.

The Family.

A man	mār
Old man	ngurram
Youth	nguin-nguin-mār
Boy	wurran
Elder brother	wartai
Younger brother	koko
Father	pipai
Mother	ngerang
Mother-in-law	nullinyur
A woman	dhunnumbur
Old woman	ngurramdyar
Girl	barraty
Child (neuter)	tukui
Elder sister	kukkai
Younger sister	kokodyar

The Human Body.

Head	pim
Forehead	mittin
Hair of head	ngarat
Beard	ngarañ
Moustache	munūtyir
Eye	mirng
Eyebrow	tharruing mirng
Nose	kappung
Ear	wirng
Mouth	ngulang
Lips	wuru
Teeth	thūngang
Mammæ	murtung
Umbilicus	rikut
Abdomen	thukung
Tongue	thallan
Chin	buluñ
Back	wirk
Arm	wūrk
Shoulder	pakkuran
Elbow	thalling
Hand	marang
Thigh	wurkarriman
Knee	purrañ
Foot	thinnang
Blood	kerik
Fat	pippul
Bone	bukkan
Penis	wirrung
Scrotum	burung
Vulva	mulun
Urine	kirng
Excrement	gunang

Inanimate Nature.

Sun	thirrung
Moon	dhenget
Stars	kukkadhing
Thunder	murndal
Lightning	murthung
Rain	murriang
Rainbow	dhārnt-burrut
Fog	wallat
Frost	mikkur
Hail	puttirang
Water	purrity

Ground	miring
A Stone	murrai
Sand	kulak
Light (of day, etc.)	nēanan
Darkness	burun
Heat	kalluñ
Coldness	bullabety
Camp	wurn
Camping place	limbity
Fire	wien
Smoke	thueng
Food	mutthal
Day	dhinggatmirring
Night	burun
Dusk	burunggittian
Hill	kang
Sandhill	pangat
Grass	karriwan
Leaves of trees	dhirrang
Bird's nest	wurnung
Egg	mirkinyung
Honey	wirraty
Path	dhā-urn
Shadow	ngakuyung
Tail of animal	wirranyung
Summer	kalluñ
Winter	pullapity

Mammals.

Native bear	winggil
Dog	gal
Wild dog	burnang
Opossum	guramuk
Kangaroo-rat	barrut
Native cat	kuppŭng
Bandicoot	warrun
Water-rat	murung
Porcupine	willangalak
Kangaroo	gurañ
Platypus	ngullirtil
Flying squirrel	wēthity
Small squirrel	ngundaty
Ringtail opossum	wiyan
Bat	ngunni-ngunnity

Birds.

Laughing jackass	gunit
Crow	wang
Curlew	wiruk
Plain turkey	burriam
Native-companion	kurun
Pelican	kurtpirrap
Swan	kunuwar
Wood-duck	ngawurk
Quail	ngarēn
Eagle-hawk	ngianggara
Emu	kapirng
Common magpie	kirre
Black magpie	munyukil
Black-duck	dhurbang
Mopoke	mŭmgaty
Bronze-wing pigeon	gure
Rosella parrot	kurtkurty
Parrokeet	yukuty
Kingfisher	bunbungwarpit
Peewee	thulirm
Plover	pitthirrit
Corella	kurogity
White cockatoo	ngaiyuk
Woodpecker	dindēn
Mountain parrot	kalingai
Small nightjar	yerradhaher

Crane	kukap
Black cockatoo	willan

Fishes.

Black fish	yim-yim
Trout	dhurkurt
Eel	kuyang
Frog	dhiamp

Reptiles.

Sleepy lizard	yuruk
Carpet-snake	kurang
Black-snake	muwang
Tiger-snake	wangaluk
Jew-lizard	wirinyurn
Small lizard	mūnni
Whip-snake	kirdōk

Invertebrates.

Locust	billirt
Blow-fly	wurul
Louse	barum
Nit of louse	lirt
Bulldog ant, black	wulakai
Bulldog ant, red	kumal
Centipede	thirrimbangarak
Jumper ant	birpirk
Maggot	thirtui
House fly	minnik
Grasshopper	nger-nger
Spider	buñ-buñ
Mosquito	murukar
March fly	murun
Mussel	thalup

Trees and Plants.

Ti-tree	kūrang
Wattle	karrang
Pine	murrung
Oak	ngēring
Cherry tree	pallat
Red gum	bial
White gum	lēng
Honeysuckle	wirraty
Bullrushes	burtity
Yam	gērang
Broom	bunung
Blackwood tree	mūtthang
Peppermint	wurut
Stringybark	marañ
Box tree	karran
Ironbark	yirip
Bush tree	wirriks

Weapons, etc.

Tomahawk	mutyir
Koolamin, wood	bupir
Koolamin for grubs	yurom
Yamstick	kunnak
Jagged spear	dhuluwarn
Hunting spear	dēr
Reed spear	ngiren
Fishing spear[1]	koyōt
Spear lever	ngarrung
Spear shield	kirram
Waddy shield	mulkar
Fighting club, bent	murduang
Hunting club	bippin
Club, with knob	munup
Boomerang	lettalettim

[1] There is a bone spike, called *killip*, fastened to the striking end of the koyōt or fishing spear.

Plaything (wooden)	wity-wity
Net bag	kurēra
Canoe	dhurung
Belt	murum
Kilt	burrandity

Adjectives.

Alive	boandian
Dead	kulpiran
Large	muryarrung
Small	gurnung
Long	wurumbēt
Short	mulubēt
Good	ngutyung
Bad	ngummindyar
Thirsty	kurangan
Red	gerrigerrigundity
White	ngapgority
Black	miñ
Quick	wungura
Slow	gurpippa
Blind	kundity
Strong	ngarakithung
Afraid	kuninbity
Tired	barbangan-mirringa
Hot	kalluñ
Cold	pullapety
Angry	watthanlingan
Sleepy	wandyangan
Greedy	murkappu
Sick	ngullarwano
Stinking	wumbity
Pregnant	karrawian

Verbs.

Die	kalpirmity
Eat	thakian
Drink	thathin
Sleep	yuin
Stand	kartan
Sit	nginggan
Talk	lakan
Tell	kuyin
Walk	yanmin
Run	karkurtmin
Bring	wambakē
Take	wambaku
Break	yēnhin
Strike	burte
Arise	mirtako
See	nakin
Hear	wangin-mirri
Listen	wangity
Give	woke
Sing	litbity
Weep	lumin
Steal	kurunmin
Ask	kuein
Climb	kurwurniñ
Conceal	yunbin
Jump	wurnbin
Laugh	wiakan
Scratch	wirrinity
Send	yumbin
Swim	yawin
Spit	thukipin
Throw	yarndin
Whistle	dhēgirnin
Vomit	kurnan
Dance	kūrwin
Go	yanmin
Come	kaka
Burn	bawa
Bite	būndin
Fly	mirtan

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Initiation Ceremonies of Victorian Tribes.

Under this heading it will be sufficient to mention that I have elsewhere described some important ceremonies of initiation in use among the native tribes of Victoria. I have given full details of the Wonggumuk ceremony, which is in force over the central and northern portions of that State. I have likewise reported the Kannety initiation ceremony, practiced by the tribes inhabiting the southwestern districts of Victoria. Other inaugural ceremonies used in eastern Victoria and elsewhere are described by me in a contribution to the Anthropological Society at Washington, already referred to in this paper.

Folklore.

The following stories were told me by some old aboriginals of the Hopkins and Eumeralla rivers in western Victoria, and as I have never seen them in print, they are included in this paper.[1]

Tyuron, the Eel Spearer.—Tyu-ron, a man of the Kappaty phratry, was a notable ancestor of the plovers. He carried a fish-spear on each shoulder when he went fishing, because he was equally dexterous with both hands. He frequented swamps and shallow streams where eels were plentiful, and never hunted for any other kind of food. He was a very agile fellow, and kept a sharp lookout along the margin of the water. When he saw an eel, he struck at it with one of his spears, and threw it out on the bank. He then ran along the edge of the water, and stood a little while looking for his favorite fish. If none were visible, he again ran on, and stood watching. He continued running up and down the stream, or around the margin of the lagoon, until he had caught as many eels as he required.

Tyuron used to paint his breast and the under sides of his arms with pipe-clay, so that the eels would not readily observe him, and sang at intervals, "Pittherit, pittherit." This is why the plover still carries the point of a fish-spear on either shoulder, and likes to remain near water. He also continues his old habit of running a little way and standing still, then running on again. And he still sings his old song, from which he has received his onomatopœic name of *pittherit*.

Mŭrkupang and Mount Shadwell.—Among the remote ancestors

[1] See my *Folklore of the Australian Aborigines* (Sydney, 1899).

of the Girriwūrru tribe there was a man of great stature, named Mŭrkupang, whose body was covered with hair. He dwelt in a cave on the Hopkins river, in the vicinity of Maroona. His *nullanyurung*, or mother-in-law, resided near him, and one day she sent her two grandchildren to see Mŭrkupang and ask him for some food, because according to tribal custom she could not herself approach her son-in-law. As he had not been successful in the chase for a day or two, he killed the children and ate them.

Fearing the retribution of his mother-in-law's friends, Mŭrkupang left his habitation at dawn next morning and journeyed down the Hopkins river to a place near Wickliffe, where he tried to make a cave in a rock by pulling loose pieces off with his hands, but he did not succeed. He next went on to Hexham, and saw in the distance Mount Shadwell, with its rocky sides. He approached it and saw a suitable cave in one side near the top. Being a great conjurer or sorcerer, he commenced "bouncing" or scolding the mountain, and commanded the portion containing the cave to come down nearer to the plain on which he was standing. He stamped his feet and made passes or signs with his hands while he sang a magical song, and presently a large piece of the mountain containing the cave parted from the rest of the hill.[1] Mŭrkupang ran away across the plain, and shouted to the fragment of mountain to follow him. After a while, when he thought he had reached a good camping place, he turned round, stamping his feet and using other menaces which caused the mountain fragment to stop. It then settled down and became what is now known as Flat-top Hill.

Mŭrkupang then selected a place sheltered from the weather by an overhanging rock—a sort of cave—and made his camp there. In a few days' time his mother-in-law tracked him to this retreat. She had with her two young fighting men of the Gurogity phratry, who were clever "doctors" and had some knowledge of magic. While Mŭrkupang was out hunting, these warriors hid themselves near the cave entrance, one on each side. They covered their bodies with stringybark, softened by beating, so that they could roll it around their bodies. This was done to prevent Mŭrkupang's dogs from scenting them. After a time the hunter returned, carrying a large kangaroo which he had caught. As soon as he went

[1] The natives point out a depression in one side of Mount Shadwell from which Flat-top was disrupted.

into the cave, the warriors emerged from their hiding-place and walked to the entrance, with their weapons ready for an attack. When Mŭrkupang saw them, he went through some very obscene antics,[1] in the hope of throwing them off their guard, so that he might get a chance to strike one or both of them, but all to no purpose. The warriors divested themselves of their stringybark coverings, with which they stopped up the mouth of the cave. A fire was then applied to this inflammable material, which made a great flame and suffocated Mŭrkupang. His spirit flew out of the cave and became a Mopoke, called by the natives *mŭmgŭty*, a bird which goes about at night.

Sociology.

In a former article published in 1898,[2] I gave a short description of the social organization of the tribes occupying the southwestern districts of Victoria, but since then I have again visited the natives of those localities and obtained further information which will now be briefly stated.

If we assume an approximate line drawn on the map of Victoria from Geelong *via* Castlemaine to Pyramid Hill; thence *via* Lake Tyrrell to a point on the boundary between Victoria and South Australia where the thirty-fifth parallel of latitude intersects it; thence along that boundary southerly to the ocean; and thence by the seacoast easterly to the point of commencement at Geelong. Then the people composing all the tribes within the region thus described are divided into two phratries, called respectively Gurogity and Gamaty, or dialectic variations of these names. But upon making a closer examination of the constitution of these phratries, we discover that the details of their composition among the tribes in the northern portion of the above region differ from those in the southern or coastal portion. I will first deal with the tribes occupying the country north of the main dividing range, where the rules of intermarriage of the phratries and the descent of the progeny are as under:

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[1] "The Nguttan Initiation Ceremony," Proc. Amer. Philos. Soc., Philadelphia, Vol. xxxvii, pp. 69–73.

[2] "The Victorian Aborigines: Their Initiation Ceremonies and Divisional Systems," *American Anthropologist*, Vol. xi, pp. 325–343, with map of Victoria.

Table No. 1.

Phratry.	*Husband.*	*Wife.*	*Son.*	*Daughter.*
A.....	Gurogity	Gamatygurk	Gamaty	Gamatygurk
B.....	Gamaty	Gurogitygurk	Gurogity	Gurogitygurk

All creation, animate and inanimate, is divided into Gamaty and Gurogity. Attached to each of these phratries are groups of totems, consisting of animals, plants, the heavenly bodies, the elements, etc., lists of a number of which were given in my former treatise.[1]

There is a further subdivision of each phratry into what may be called clans or sections, with distinctive names, taken in some instances from animals and in others from inanimate nature. Each subdivision comprises a number of families bearing different totem names. That is, all the totems of a phratry are apportioned among the sections, some sections (or clans) possessing a certain aggregate of totems and some another. Every individual of a tribe claims some animal or inanimate object as his totem.

Again, each of these clans has its own spirit-land, called *mi"-yur*, to which the shades of all its members depart after death. The miyur of a clan is located in a certain fixed direction from the present hunting grounds of the tribe, but the direction of the miyur of each clan differs from that of the others. It may be situated far out in the desert country of the mallee-scrubs, or away towards the setting sun, or in the distant rocky mountains, or elsewhere.

When a member of a clan dies and is buried, the body is laid horizontally, face upwards, with the head placed towards the part of the horizon which leads to the miyur or spirit-land of the clan to which the deceased belongs. These miyurs are divided into the same two phratries as the people of the tribe. The spirit of a Gurogity man or woman goes to a Gurogity miyur, and a Gamaty spirit travels away to a Gamaty resting-place, conformably to the spirit-home of his clan.

Each spirit-land has its own description of water. For example, in one miyur the water is gray, in another sparkling, in another reedy, in another dark blue, in another reddish, and so on.

Between the main dividing range and the seacoast the phratry

[1] *American Anthropologist*, Vol. xi, pp. 333–334.

names and their feminine equivalents are slightly different from those just described, as shown in the following synopsis:

Table No. 2.

Phratry.	*Father.*	*Mother.*	*Son.*	*Daughter.*
A.....	Gurogity	Kappatyar	Kappaty	Kappatyar
B.....	Kappaty	Gurogityar	Gurogity	Gurogityar

Everything in the universe is divided between these two phratries. Among the totems of Gurogity are included the following: Dog, flying squirrel, small squirrel, pelican, eagle-hawk, white cockatoo, tiger snake, red bulldog ant, red gum tree, oak tree, bloodwood, broom, peppermint, ironbark.

The undermentioned are some of the totems of Kappaty: Native cat, kangaroo, crow, swan, bat, crane, black cockatoo, whipsnake, black bulldog ant, white gum tree, wattle tree, cherry tree, honeysuckle, stringybark, tomahawk, reed spear, boomerang.

The totemic families belonging to Gurogity and Kappaty are subdivided into clans or sections, somewhat similar to those in use among the tribes already described, but not so numerous or elaborate. They likewise have a spirit-home, which some of the tribes call *maioga* and others *mungo*. Every individual, when buried, is placed with the head pointing in that direction, and all the spirits go away to the same resting-place. This is an island, called by the white people Lady Julia Percy Island, situated off the coast of Victoria, about halfway between Warrnambool and Portland. On the shore of the mainland there are some rocks like stepping-stones stretching out into the sea towards the island. These rocks, some old black fellows told me, were purposely placed in that position, in the far away past, by the spirits of clever men, to enable their fellow-countrymen to reach their maiogo. The spirit of a deceased person walks on the land to the shore and springs out to a rock, then to another and another rock, and lastly makes a final bound over the intervening sea and alights on Lady Julia Percy Island, the native name of which is Dēnmār.

THE MISSISSIPPI RIVER PROBLEM.

BY LEWIS M. HAUPT.

(*Read February 19, 1904.*)

In the economic development of the Federal Domain, the fostering care of a paternal Government has been liberally extended, by Congress, to the granting of homesteads to actual settlers; to the reclamation of arid lands by irrigation; to the donation of swamp lands to States for educational purposes; to the subsidizing of the overland railroads by extensive land grants and to the setting aside of large tracts for the Indian tribes for ranges, and in many other ways has it stimulated the enormous traffic and wealth of the country.

Still there are waste places which may be made to blossom for a relatively small sum of money, but which cannot be rendered habitable at the expense of the individual settler, and undeveloped communities are likewise unable to reclaim extensive tracts from a foe which may attack them from all sides. General defensive works are of paramount importance to protect property and encourage the settlement of the richest land in the world, and it is manifest that the burden of this reclamation should be borne by those who derive the benefits from the increased yield, namely, the consumers as well as the producers.

But there are great and honest differences of opinion as to the methods which should be followed to secure these results.

The local owners and settlers firmly adhere to the reclamation of their land by levees to exclude the water, regardless of the ultimate consequences from confining the floods to a greatly congested bed They fail to realize that if the fertilizing silt is excluded from the plains it must be dropped in the bed of the river and cause it to rise, and impair navigation as well as increase the menace to property.

The great necessity for reclamation and protection works seems to have beclouded the issue, and undue stress is laid upon that particular phase of the problem, whereas the intention of the Government, as originally proposed, was to open the channel and control the stream for navigation.

These two purposes are so distinct in character as to claim separate jurisdiction under different departments of the Government,

and are both mutually dependent upon Government appropriations for a successful issue. Works built to reclaim land are not generally well adapted to the creation and maintenance of channels, as will appear from the experience cited later in this paper, and hence the demand for a system of levees which shall at the same time protect the land and create a navigable channel is incongruous, and will also be found to be opposed to existing statutes.

Much greater progress in both directions, it is believed, can be made if the two issues are divorced and separate plans be devised for each on its merits.

In this connection it will be found suggestive to note some of the divergent views expressed by the speakers at the Levee Convention, held at New Orleans, October 27–28, 1903.

It was said, but not by engineers, that "protection can come only from a national system of massive dikes . . . . the system of reservoirs (is) utterly unfeasible and impossible." . . . . "Outlets are not only impracticable but harmful." A distinguished member of the Mississippi River Commission stated: "The progress of levee extension has been a repetition of the early history . . . . their upward extension has cut off more and more of the former overflow. . . . . The necessary result has been to raise the flood level higher, and so make it necessary to build the levees higher. . . . . The last flood has left behind it a record of mingled disaster and success."

On the other hand the Committee on Resolutions reported that the investigations made by the Commission "wholly disproves the notion, which still prevails to a considerable extent, that the immediate effect of levee construction is to cause the bed of the Mississippi river to rise. If this were true it would necessarily follow that the levees would need to be continuously strengthened and elevated, and thus all hope of protection would have to be abandoned." Thus the case is prejudged by its advocates.

But another close observer remarks: "You are not wise if you do not see that the drainage from this vast basin (the Missouri) will flow into your river faster than you can raise your banks, and the levee system will in time prove a failure. . . . . If you go on and complete your levee system as you desire to, in less than twenty years you will be clamoring for some system to get the silt from the water back upon your lands for the fertilization of your plantations."

Again it was urged that the confidence inspired by the levees had caused the value of property to advance "all over the alluvial valley, in some places 100 per cent., in some places 200 per cent., in some places 300 per cent"; but a distinguished Senator calls attention to the fact that Congress," under the Constitution, had no power to appropriate money to protect private property. I want to say to-day that every dollar that has ever been appropriated for levees on the Mississippi river has been on the theory that it would benefit navigation, and we never dared to put it on the ground, up to this day, that it would benefit private landowners, though we knew of course that it was incidental to it."

The success or failure of this improvement must, therefore, hinge upon the ability to prevent the elevation of the bed and its silting up by the larger amount of sediment confined to its channel and the relief of the excessive high stages by other expedients than levees, and it is to the consideration of this question that the following pages are directed.

A Method of Controlling Floods on Mississippi.

Prior to the Louisiana Purchase in 1803, the territory of the United States was limited to the area east of the Mississippi river and north of the Spanish possessions in Florida, giving no independent outlet for the products of the republic other than that across the Appalachian Mountains to the Atlantic Ocean.

By the purchase of the territory extending from the mouth of the river on the Gulf to Puget Sound on the Pacific, the United States came into peaceable possession of the most fertile and productive region within its borders and secured control of the navigation of the greatest river in length on the globe.

Up to the middle of the last century the population was comparatively sparse and the products limited, but after the restoration of peace and the opening of the country by roads and railroads, the development became so rapid as to require a systematic and comprehensive effort to regulate and control its avenues of interstate and foreign commerce under the control of the general Government.

The frequent casualties to the palatial steamers traversing these western waters from snags, bars and shifting channels with insufficient depths finally led to the organization of the Mississippi River

Commission in 1869, for the purpose of permanently improving the stream from the head of the Passes to the headwaters.

The duties of the Commission as set forth in the law of June 28, 1879, read as follows:

"Section 4. It shall be the duty of said Commission to take into consideration and mature such plan or plans and estimates as will correct, permanently locate and deepen the channel and protect the banks of the Mississippi river; improve and give safety and ease to the navigation thereof; prevent destructive floods; promote and facilitate commerce, trade and the postal service; and when so prepared and matured to submit to the Secretary of War a full and detailed report of their proceedings and actions, and of such plans with the estimates of the cost thereof, for the purposes aforesaid, to be by him transmitted to Congress; *provided*, that the Commission shall report in full upon the practicability, feasibility and probable cost of the various plans known as the jetty system, the levee system and the outlet system, as well as upon such others as they deem necessary."

This was the authority for the subsequent systematic improvement of the river, which has proven to be an impressive object lesson as to the greatness of the problem and the difficulties to be overcome.

After so many years of experience, with a large amount of reliable data at hand, and with the voluminous discussions, more or less acrimonious, between the advocates of various systems, it may be profitable to weigh dispassionately some of the evidence and note where we are trending.

This may be done best by quoting the language of the Commission itself in the Report of 1903, just published:

"Systematic work, which has for its object to permanently locate and deepen the channel, has not been practicable under existing conditions. In the limited extension and repair of bank protection and contraction work the Commission has, however, kept in mind that the permanent improvement of the river is contemplated by the organic act, and experiments are continually being made looking to the best use of available material and the development of appliances and methods which may be economically and effectively employed when Congress shall provide for such a systematic improvement."

From which it appears that the permanent and systematic plan

is still conditioned upon the results of experiments and further legislative action by Congress.

Prior to the organization of the Commission a Special Board of five United States Engineer officers was appointed July 8, 1878, to report a plan for the Improvement of Low-Water Navigation, and on the 25th of January following, the report was submitted, recommending the general plan of "contracting the channel to an approximate low-water width of 3500 feet by means of dikes of brush, etc., and where the bed of the river is found to be too hard to be worn away by the river currents, dredging, in addition to the reduction of width, to be resorted to."

In this report attention is directed to the fact that "there is an ample depth wherever the thread of the current follows a well-marked concave bank. Also wherever the low-water width does not exceed about 3500 feet," and, conversely, navigation is bad wherever there are straight reaches and the width exceeds this limit. Another element of serious importance is the great instability of the channel, which shifts through a breadth of several miles, due to the caving of the banks, which proceeds "at the rate of 200 to 300 feet a year in certain places, and these amounts are sometimes much exceeded."

As to the available depths at that date, the report states that "there are forty-three places between Cairo and the mouth of the Red river where low-water depths of less than ten feet and thirteen where depths of less than five feet may be found. . . . . There were fifty-two days on which the least depth of water between St. Louis and Cairo was less than six feet, and sixty-nine days when it was less than ten feet."

These considerations led the Board to conclude that "protection of caving banks will therefore be needed. . . . . To thoroughly regulate the river caving, even in those bends which have deep water below them, should be stopped. . . . . The protection of these caving banks can be effected by mattresses. Where the water is deep it will be very expensive." . . . . "That such a trial may thoroughly test the practicability and the cost of regulating the river and increasing its low-water depth, one of the worst places on the river should be selected."

Accordingly the Board recommended the appropriation of $600,000 for revetments on the Plum Point reach, one hundred and sixty miles below Cairo, which was granted and the test made.

Extensive revetments were also applied at Lake Providence and other points on the river, but the difficulty of holding them against the great pressure of the floods and their enormous expense have led to their abolition.

This Board of Engineers also reported on January 25, 1879, upon the effects of a permanent levee system throughout the length of the river below the mouth of the Ohio, not only upon the low-water navigation but also of the benefits it would confer in affording protection and giving needed facilities to shipping, commerce and navigation in the high stages of the river.

The Board found that "levees have no direct action except when the water is high. . . . . A glance at the sketches is sufficient to show that levees, even if they come into action every high-water stage instead of only every 'flood,' would have little or no influence on the low-water navigation. They would leave to the river its inordinately great width and area of shifting sands, and exert little or no influence on channel formation. This would be the fact even if they everywhere followed closely the natural banks. . . . . Closely adhering levees which in all high stages shall confine the water which now escapes into the swamps would, by an increased current action, accelerate the caving of the banks in the bends and enhance the instability of the bed, which now not only makes the work of navigation improvement so difficult, but is one of the most formidable foes to a permanent levee system. . . . . The great obstacle to the improvement of the low-water navigation and to maintaining a levee system is one and the same for both, viz., the instability of the river from the caving of its banks. . . . . We believe that the levee system, if undertaken, should be matured and developed in connection with the navigation improvement."

Hence it appears that this Board attached but little importance to the use of levees as an aid to the formation of a navigable channel, although recognizing their value in the reclamation of land.

It relied upon the regulation of the channel by dikes and revetments to correct the evils, but the past experience has destroyed this expectation and compelled a change of policy which it may be well to review as to its consequences.

After the greatest flood to that date, which occurred in 1882, the Commission reported that the controlling depths at low stages between Cairo and Plum Point reach were but five and one-half and six feet; that a large amount of the revetment had been lost, and

that to determine the effect of outlets surveys had been made during and after the large crevasses caused by that flood, from which it was concluded that the relief which might have been anticipated from the decrease of flow below the outlet was not realized, because the water thus released returned to the river lower down and obstructed the discharge at that point, making a water-dam.

It should not be concluded from this fact, however, that outlets are injurious, for it is not proposed to permit the excess of water immediately to flow back to the lower reaches, but to impound it for a considerable time in large reservoirs, thus changing entirely the conditions and removing the objections to the ordinary operation through natural crevasses, which are wholly different from the impounding reservoirs proposed by Mr. Seddon for the relief of the floods.

This Commission reiterates its statement "that for purposes of channel improvements merely, the limit of economy is reached with the confinement of the ordinary flood. The result of this qualification is that the building of levees to the height necessary to protect the alluvial basin from overflow, is not necessary as a part of the logical plan of river improvement." This policy was doubtless reflected in the legislation which followed, making it illegal to appropriate money for protection works unless they were found to be beneficial to navigation.

The Joint Resolution passed March 3, 1891, *re* Mississippi river levees, reads as follows:

"*Resolved, by the Senate and House of Representatives of the United States of America in Congress assembled,* That the sum of one million dollars is hereby appropriated, to be paid out of any money in the Treasury not otherwise appropriated, for the improvement of the Mississippi river from the head of the Passes to the mouth of the Ohio river, which sum shall be immediately available and shall be expended under the discretion of the Secretary of War, in accordance with the plans, specifications and recommendations of the Mississippi River Commission; *Provided,* That no portion of this appropriation shall be expended to repair or build levees for the purpose of reclaiming lands or preventing injury to lands or private property by overflows; *Provided, however,* That the Commission is authorized to repair and build levees, if in their judgment it should be done, as part of the plans to afford ease and safety to the navigation and commerce of the river and to deepen

the channel; *Provided, further*, That the office, clerical and traveling expenses and salaries of the Mississippi River Commission may be paid from this appropriation.

"Approved, March 3, 1891."

From this law it appears that, unless the levees are beneficial to the navigation, there is no warrant for the application of Government funds to their construction and maintenance; hence it happens that there is great difference of opinion as to the results produced by them, and it is strenuously urged, doubtless in good faith, by those on whom the burden of levee construction falls so heavily, that the river bed is *not* rising, nor is the channel shoaling, while on the contrary the actual and carefully conducted surveys made by the Commission indicate an unmistakable reduction in the depth and area of the low-water channel, and an increase in the caving and instability of the banks with greater flood elevations than before, as will presently appear.

The logical inference from these data would seem to point conclusively to the necessity for a modification of the levee system and a resort to one which will relieve the floods, while at the same time it reduces their height and also maintains a more constant low-water stage, with greater depths for navigation. Under such a system the Government *would* be fully justified in making appropriations for maintaining low levees, supplemented by outlets and receiving basins for storage of the excess of flood waters.

This involves the removal of all bars or obstacles which retard discharge, beginning at the mouths and proceeding up stream; the readjustment of the alignment at the gorges and the construction of reservoirs in the swamps, especially of the St. Francis basin.

Before leaving the report of the Commission of 1883, it is desirable to state further that, under the views as above outlined, the estimate for the "levees on the Mississippi river at certain grades" aggregated $11,443,770; but it recommended the "closure of the gaps in the existing levees along the Yazoo and Tensas fronts, begun a year ago, as the most economical and shortest method of shutting off the escape of water into those great reservoirs, and securing so far the benefit of the entire discharge in the improvement of the channel. Beyond that the Commission is not prepared at this time to make any specific recommendation for construction of levees as a means of channel improvement, and reserves the subject for further consideration."

In closing the report the Commission calls attention to the peculiarly favorable conditions of the outlet section of the river in these words:

"In conclusion of this subject, the Commission considers it necessary to call the attention of Congress to peculiar conditions existing below Red river. This section of the river is in a state of much greater stability than is found in any other part of its course below the junction of the Missouri. At a short distance below Red river it becomes narrower and deeper. It has been leveed throughout for a great many years. No flood complications arise here, as above, from the return of overflow water which has escaped from the river at points higher up. This all reaches the sea through the numerous delta bayous on either side."

This reach, therefore, furnishes the best object lesson available as to the proper treatment of the river, and is a complete answer to the objections to the use of outlets, for the volume of discharge, when in flood, is only about one-half that of the river above the mouth of the Red, and yet the depths are more than ample, reaching in places to two hundred feet. The escaping waters do not return to the bed but are permanently withdrawn, and there are no such variation of channel widths as are to be found between the lines of levees as constructed in the higher reaches.

The President of the Commission, however, did not coincide with the majority on the question of levees and outlets, with reference to which he said:

"Considering . . . . the probability that the height of floods will increase in the future, it seems proper that in the plan for any general system of levees, if the principle of keeping out all floods, whatever their height, should be surrendered (a step of doubtful advisability), the plan should at least provide for holding a flood like that of 1882. A thorough study of the subject of levees has not yet been made; until then accurate estimates are impossible. . . . . Such as they are they make it impossible for me to concur in the estimate of $11,443,770 as the cost of a general system of levees from Commerce, Mo., to the Forts, adequate to preserve that country from destructive floods."

From the foregoing records it appears that the Commission, after a careful investigation covering about fourteen years, had little or no confidence in the ability to regulate the river by revetting the

banks, and no faith in high levees to improve the navigation at low stages.

Consideration of the problem continued and many of the most experienced engineers on the works participated in the discussion.

The local Levee Boards of the several States were obliged to continue their protection works, which were assuming greater proportions as the system was extended, and great pressure was brought to bear upon the general Government to aid in the work of defending the arable land from overflow, and thus confine the floods to the narrower channel between the artificial banks.

As a matter of record it is important to note the arguments advanced by the competent and conscientious men in charge of these works.

In November, 1892, the Chief Engineer of the Yazoo Levee Board stated that "the levee system, which is the one now in vogue, has been objected to on several grounds—that it was very costly, that it was very dangerous, and that it exposed the river to deterioration from the confinement of silt, causing the deposition of silt in the bed of the stream."

In reply to these objections he says that up to that time the cost would probably be covered by $35,000,000, and that to build the levees to a height now (1892) considered sufficient, namely, five feet above the highest recorded floods, would require some $20,000,000 more. He adds there is no difficulty in making levees that will secure against disaster. The flood of 1892 was one foot higher than ever before, but there was no break along the Yazoo front; and the third objection, as to elevation of bed, he repudiates as opposed to all testimony.

In his report on the flood of 1903, his successor, also an engineer of long experience on the river, states that the present flood reached a stage exactly three feet above that of 1897, and was prevented from reaching a higher point by the two large crevasses which occurred in the St. Francis basin levees two or three days before the culmination of the flood at Memphis. Correcting for this and the lower gauge reading at Cairo, the present rise might have reached an elevation of four feet above that of 1897. Below Burk's Landing, within the next few miles, are four unclosed crevasses that occurred in 1897, aggregating over a mile in width. There was a crevasse at Rescue Landing in 1897, which lowered the stage locally nearly one foot. He suggests that the grade line of 1897,

which was a little under five feet above the flood-plane of that year, should now be raised to five and a half feet. He also foresees the still greater dangers from increased floods, and suggests in places the construction of reserved and subsidiary lines of levees to cover the emergencies arising from the increased caving of the banks.

The report states: "With a considerable addition to the high-water elevation that may be expected in the near future, it may be assumed that the current force and the general difficulties of the situation will be further magnified."

With reference to the dangers from caving banks he reports:

"The situation here (near Rescue) has become still further complicated to a grave degree by the accelerated rate of caving of the river bank opposite the new levee, which threatens its destruction from that source in a comparatively few years. The greatest development is about the middle point of the new levee, where the bank has receded nearly five hundred feet since November, 1898, with less than seven hundred feet remaining to the levee. In order to retire this line to a more secure location it will be necessary to fall back into very low ground, which would still further magnify the difficulties to be encountered. In view of the foregoing facts the conclusion seems inevitable that the maintenance of the front line extension as a permanent feature of our levee system must be abandoned." . . . . "Any further effort to hold this levee end will be well-nigh hopeless of good results."

Again he says:

"The instability of the foundations of the Ward Lake line has been very much in evidence already. With an increase of five or six feet of water pressure this evil will be increased to an unknown but undoubtedly great extent, and will probably require a secondary line, in the nature of a sub-levee, throughout most of its length.

"From renewed activity in caving of the bank along the Burk front, it seems now probable that about one and one-half miles, and possibly more, of that levee will have to be renewed within the next few years." The instability of the bed is further shown at the head of Island 63, where the river is returning to the old channel on the Mississippi side. "This development threatens the stability of some three miles of levee above Burk's Landing that was heretofore considered reasonably secure."

"It has been forcibly demonstrated by this high water that one of the greatest problems of the future shall be to combat the dan-

gers arising from defective foundations of the levees; that is to say, from the permeable and treacherous character of the natural earth foundation, which permits the passage of large volumes of water beneath the levees. This water is forced up by hydrostatic pressure through every aperature or weak place in the crust above. The flow in many cases comes with great freedom, bringing up large quantities of sand and leaving a corresponding displacement of material under ground. . . . . This agency will increase in energy as the river goes to higher stages in the future and demands thorough and systematic treatment."

The estimates submitted to the State Board for work of primary importance aggregates $627,000, of which $441,000 is for new levees.

From this evidence it appears that there is some "difficulty in making the line secure against disaster," and that large breaches have actually occurred; also that there is an ever-present danger of failure in the most vital part of every structure, namely, the foundation, from the constantly increasing head due to the concentration of the waters, and that the increasing caving of the banks requires not only new lines but reserved levees, thus greatly adding to the cost.

The estimates previously submitted as being suffioient to complete the system have been several times exceeded, and it is now stated that to bring the levees up to a safe standard will require about forty per cent. more material than has been already put in place.

But there is no well-defined limit to the height or extent of the works, since the river is not controlled nor the erosion reduced.

A distinguished engineer, employed on the river for many years, states: "The uncertainty as to future flood volumes and the stages consequent upon a confined channel are so great, however, that the great devastation from crevasses, caused by the river overtopping the levees, will continue for many years to come. The banks will never be fully protected from caving, and the channel will always be very unstable and will shift more or less in position. . . . . The effect of the levees is to increase the height of the bars so long as the very unequal widths are uncorrected, for a confined river means higher flood stages, and the higher the stage the higher the bars are built up in the wide reaches. Therefore, the regulation of the width and the protection of the banks should precede the building

of the levees. But the popular demand for levees has reversed this order."

It would seem, therefore, that in consequence of the instability of the bed and banks with their superimposed levees and the increasing heights of the floods, the question of the ultimate cost is indeterminate but great.

In military practice it is found to be good tactics to disperse an enemy and attack him in detail, but the levee system appears to reverse this mode of procedure and concentrates the energy of the flood for a thousand miles, so that if there be a weak point in the ramparts it will assuredly discover and breach it.

The third point of contention has been discussed *pro* and *con*, but is of such importance that a few citations are deemed necessary to state its status. For example, it is said:

"The cross-section of the river will gradually rise, and has risen *where not leveed*. . . . . It is not claimed by the advocates of the levee and contraction system that there will be an appreciable or immediate lowering of the bed of the river. . . . . It will take many years. . . . . But that the raising of the bed to any measurable amount in centuries to come will take place is not admitted." The writer then cites the Po.

In other words, the levees have no appreciable effect on the elevation or the depression of the low-water, or even on the high-water, channel in any sensible period of time. If so, there is no justification for their construction as aids to navigation, and hence no warrant for the appropriation by the general Government.

The Po, which is so frequently cited as an illustration that the bed is not rising, appears to be much misunderstood.

One of our most distinguished United States Engineer officers is quoted as saying: "The river Po has long been leveed, and it is often stated that its bed has risen largely in consequence of levees. The following data will show how unfounded is the statement that the bed has risen by amounts that are of much importance." He then adduces the data in the form of gauge readings and adds: "The above gauge readings, which have been kept only since 1807, show that there has been no important rise of the river bed (since that could not rise without raising the low-water surface) in the past sixty-eight years."

This testimony, therefore, admits that the bed does rise but minimizes its amount, and falls into the error of assuming that the eleva-

tion of bed is reflected in that of the surface as recorded by the gauges. That the bed may rise and yet the gauge readings diminish, will be apparent when it is remembered that the width may be increased by caving and the area of the cross-section be increased even, with a resulting lower record on the gauges, as has happened in the Mississippi. Moreover, it is admitted that even in a state of nature or without levees the bed will gradually rise. It is, therefore, only a question of degree as to whether the rate of elevation is augmented or not by the levees.

To determine this mooted point as to the elevation of the Po, an American scientist made a personal inspection and reported his observations in 1896.[1] In his description he says, *inter alia :* "Sir Charles Lyell has been frequently quoted as stating, 'At Ferrara the surface of the water has become more elevated than the roofs of the houses.' . . . . My visit showed this danger to be less imminent than might be supposed. Its population has dwindled away from 100,000 to less than 30,000, while great stretches of land within its walls are now quite deserted. It is in a great plain only six and a half feet above the sea level. The roads across the plain are raised considerably above the general level, thus keeping them dry.

"In 1847, Lombardini showed by actual measurement that the mean height of the Po only here and there rose above the general level of the plain and was generally considerably below it, and that even during the great flood of 1830 the pavement in front of the Palace was scarcely ten feet below the level of the surface of the water in the river. Since that time, however, these conditions have altered in a marked manner, the more recent investigation of Zollikofer having shown that in the normal condition of the river the surface of the water in the neighborhood of Ferrara is somewhat over eight feet above the surrounding plains, while in flood the water in some places rises from sixteen to nearly twenty feet above the plain on either side.

"The dikes are estimated to be twenty-six feet high, and the crest is cut down somewhat to permit the road to pass through with easier grades, but the cut is closed with a brick wall arranged for stop-planks to exclude the higher floods. Though the danger is not so great as indicated by Lyell, yet the river in flood time hangs suspended, so to speak, over the surrounding plains, and the city of

[1] See *Science* of May 22, 1896.

Ferrara might be subjected to disastrous inundation should the right dike break. This danger is diminished by a secondary series of lateral embankments, placed at a considerable distance back of the dikes, along the whole course of the river below Cremona.

"The Po at this point is two hundred and eighty-five yards wide; has a swift, turbid current, and long sand bars are seen from the top of the dikes in the wide stretches, showing that in flood time a large quantity of sediment too heavy to be carried in suspension is swept along."

To a disinterested reader this description conveys the idea that the elevation of the surface of the Po has been a very appreciable quantity during the last half century, and that the bar-building forces have not been idle even in a stream of such paltry dimensions as compared with the mighty Mississippi.

L. F. Vernon-Harcourt says that—

"Numerous breaches have occurred in the embankments of the Po, resulting in the devastation of its valley; and the flood level of the Po has been so much raised that it has been decided not to heighten the embankments, for fear of occasioning still greater disasters. . . . . Some of the embanked rivers in Japan have their beds as much as 40 feet above the level of the plains above which they flow. . . . . They serve as a warning against the extensive raising of embankments to counteract the silting up of a river" (*Enc. Brit., River Eng.*, p. 588).

In his argument against bed elevation the same United States Engineer officer quotes a portion of a letter from another officer as to the condition of the Hoang Ho, who stated that he had crossed the Yellow river and visited the site of the great break, measuring the levees at various points, but that he had no instruments other than a hand-level and tape. "But," he says, "the conclusion I came to in regard to the influence of the levees upon the bed of the river was that they had nowhere filled it to a higher level than the adjacent country. . . . . I cannot but believe that Abbé Huc was entirely mistaken in regard to the silting up of the channel, and that an exhaustive survey would prove beyond doubt that no such silting as to raise any part of the bed above the adjacent country has ever taken place."

It seems almost superfluous to call attention to the indirect admission that the bed has risen, but not so much as to reach to or above the surrounding country, but it does not state that the flood height

does not reach above this danger line, as the disastrous breaks in late years attest fully. Moreover, no soundings were made and there was no basis for comparison.

But perhaps the most pronounced instance of bed elevation, due to a partial contraction along the banks of a stream near its outlet, and of which there can be no question, is that at the South Pass, where the constant and accurate surveys made since the construction of the two parallel jetties, in 1869, show they have produced an average shoaling along nearly the entire twelve miles of four inches and over per annum.

A recent Southern writer, evidently alive to the situation, stated: "The living generations will have great responsibilities in their treatment of this stalwart river, for it will not do to say that if the practice of building dikes proves ineffectual the true remedy may be applied at a later date. We know absolutely that the practice will prove ineffectual. This much we have already demonstrated in our own experience, even had we not the experience of twenty centuries to aid us in reaching conclusions; and every foot added to the elevation of the Mississippi river will be a measure of peril and perplexity for future generations. The time to apply the remedy is before the mischief is done." . . . . There should be no more Congressional appropriations for dike building, but the whole country can very properly be asked to help in providing for the security of future generations.

In the recent discussion before the American Society of Civil Engineers, it was stated that "the levees of the Po formed an immense network of dikes, which has assured the protection of a vast rich territory century after century." Also that "while the combined discharge of all the affluents amounts to 528,000 cubic feet per second, the discharge of the Po during the same period is only 176,000 cubic feet." The writer adds: "That is certainly a remarkable result, and doubtless much of it must be attributed to the fact that the tributaries do not discharge flood waters simultaneously and that the lakes retard the flow to a marked extent." . . . . He also adds: "There are, however, very serious drawbacks to levees as a means of preventing inundation, and Belgrand has stated that 'it is plain that even in a country where levees have existed for twelve centuries, where property has been exposed to all the consequences, it has not been clearly demonstrated that the advantages are greater than the inconveniences.' The chief objec-

tions are: (1) That they raise the flood heights; (2) that they break too easily and often; (3) that they cost too much; (4) that they cause the river bed to rise, because they do not permit the escape of sediment over the banks."

Moreover, it is important to note that the physical conditions attendant upon the drainage basin of the Po are wholly distinct from those of the Mississippi, since the Alpine tributaries with their steep decline of over a mile in twenty are checked and regulated by the magnificent and extensive storage and sedimentary basins of Lakes Maggiore, Como, Iseo and Gorda, from which the effluent issues comparatively clear and flows 340 miles to the sea, which is about 1260 feet below. The total basin drained by the Po covers but 27,000 square miles, while its mean discharge at the mouth is only 60,745 cubic feet, or about one-eleventh that of the Mississippi.

The benefit of the lakes as sediment basins is in part neutralized by the formation of pools in the bed of the stream, for the levees do not hug the banks closely but are in places miles apart, and they have been "so spaced at and near the mouths of important tributaries that the major bed forms a sort of reservoir, in which is stored not only the floods but still—and to disappear with time—the deposits carried by the affluents."

This disappearance takes place by the receding stage distributing the bars along the bed of the stream, thus causing elevation, as in the Mississippi, where similar pools are found to exist; so that, notwithstanding the great reservoirs on the tributaries of the Po, the defective alignment of the levees has aggravated the shoaling and bed elevation, as shown by the record.

But aside from general observations, the greatest weight should be given to the carefully conducted surveys made by the Mississippi River Commission, covering a reach of two hundred miles from the mouth of the Arkansas river to Vicksburg, and made at an interval of about twelve years, for the purpose of determining this question. The composite cross-sections of this reach show a fouling of the low-water channel to the extent of about four feet, and an enlargement of the area between low and high water amounting to nearly 17,000 square feet, due to the increased caving of the banks from the efforts of the augmented volume to enlarge its bed. This amounts to not less than 206,200,000 cubic yards of eroded material per annum in the reach of seven hundred and fifty miles from

Cairo to the Red river, from whence to the Gulf the volume is divided and the channel relatively permanent and deep. Here, even with a much flatter slope, the river is narrower and much deeper than necessary for the largest vessels, reaching in places two hundred feet and over, and yet it has been seriously proposed by the opponents of outlets to close the entrance into the Achafalaya, for fear lest that steeper and shorter route might ultimately become the main river and "New Orleans be left high and dry." As the city is on a waterway only a few feet above Gulf level, having ample depth except over the bars in the Gulf, there could be no possibility of such a calamity unless the stream were dammed at both extremities and the water pumped out. In fact it is on an arm of the Gulf, and if all the sediment were diverted through another channel it would greatly simplify the opening of the bars at the delta and improve the maritime conditions of the Port of New Orleans, which would soon be without a rival in this country. But, on the other hand, if the escape into the Achafalaya outlet were closed, the next flood would sweep away the city and all its inhabitants. This is the *reductio ad absurdum* to which the opposition to opening the outlets tends.

In short, the weight of the evidence points most emphatically to the conclusion that the building of levees materially increases the rate of shoaling in the bed of the river and the evils resulting therefrom.

From the foregoing citations it is reasonable to conclude that the effect of the levee system, *per se*, upon the navigable channel is at least negative, and hence the Commission has at length been forced to resort to the use of powerful hydraulic dredges for the purpose of temporarily increasing the depths across the bars during the season of low water. But so unstable are these cuts that in some instances they are redredged from three to four times within a few months during the low-water season, and the plant is of little use during the remainder of the year.

Moreover, under the Act of 1891, there would seem to be no authority for Federal appropriations for the levees, unless they are found "to afford ease and safety to the navigation and commerce of the river and to deepen the channel." It would also appear that the transient dredging of the bars does not fall within the requirements of creating a permanent channel, nor does it operate to "prevent destructive floods."

But "self-preservation is the first law of nature," and the local

belief in the efficacy of embankments for "the purpose of reclaiming lands or preventing injury to lands or private property from overflowing" is so innate that the occupants of such tracts are almost a unit in their demands for national aid for protection, and not without reason since they have a right to be protected in their lives, homes and property from the ravages of a common enemy from without. Since, under existing conditions, there appears to be no warrant for the application of the funds to reclamation works pure and simple, the law should be amended and an appropriation should be made directly for this purpose, independently of the commercial or navigation requirements. The lands thus reclaimed are among the most fertile and desirable within the Federal domain, and would become the source of a large volume of staple commodities for manufactures and food products. There is quite as strong an argument for the development of this portion of our territory by the exclusion of floods and their devastations, at the expense of the general Government, as there is for the fertilization of the arid lands of the Western plains by the application of irrigation. While one section has too much water at certain seasons the other has too little, and it is unquestionably the function of a paternal Government to equalize and regulate the distribution of this life-giving element for the general welfare.

To this extent and for this purpose levees are unquestionably useful, yet they are not the only resource of the engineering profession in alleviating floods and reclaiming lands. Drainage is an important factor, and this is based upon the principle of drawing down the water by gravity to lower levels and voiding it as rapidly as the topography will permit; but this important expedient has been vigorously opposed by levee advocates and set aside untried as purely theoretical, hence it is that attention is directed to a few physical facts as to the direct benefits to be derived from the opening of all possible avenues of escape of the flood waters, commonly known as the

Outlet System.

There has been much misunderstanding as to the practical application of this system, and erroneous impressions prevail as to its results in consequence of the deductions drawn from natural crevasses.

As the discharge from these openings returns to the main trunk

lower down through the tributaries, where the confluence of waters further obstructs the flow and causes deposits, it is claimed that outlets would be harmful. But this is not the condition which would prevail if properly constructed weirs and regulating works were placed so as to permit the discharge of a portion of the excess of the floods into suitably located impounding reservoirs, remote from the erosive action of the river currents. It is also claimed that the navigable channel would be injured by the reduction of volume below the crevasses and that the bed would rise in consequence thereof. This conclusion does not appear to be sustained either in theory or practice. On this point Generals Humphreys and Abbot state (page 387, *Physics and Hydraulics*), under the head of "Outlets": "This plan consists in reducing the flood discharge by waste-weirs and conveying the surplus water to the Gulf by channels other than that of the main river. The advantages of this system have been stoutly contested by many writers, on the ground that reducing the discharge of the Mississippi will occasion deposits in its channel, and eventually elevate rather than depress the surface of the river." In support of this opinion they have urged first that actual measurements upon the river at certain crevasses prove that deposits are made when the velocity is thus checked, and, second, that theoretical reasoning indicates that such deposits ought to be anticipated.

"Certain operations of this survey were conducted with especial reference to determine the effects of outlets, and they demonstrate, with a degree of certainty rarely to be attained in such investigations, that the opinions advanced by these writers are totally erroneous."

The report then analyzes the two cases cited in proof of the assertion, viz., the Fortier crevasse of April, 1849, and that of Bonnet-Carré of 1850, and shows that the phenomena attributed to the breaches were those ordinarily found to result from bends and straight reaches, and that in fact even in a natural crevasse there was no bar formed below such opening in the banks, and that "the assertions to the contrary are erroneous." They add: "There is no evidence whatever that any filling up of the bed ever did occur in consequence of a high-water outlet, and, moreover, it is impossible that it ever should occur, either from the deposition of sediment held in suspension or drifting along the bottom. The conclusion is then inevitable that, *so far as the river itself is concerned,*

they are of great utility. Few practical problems admit of so positive a solution."

Perhaps the best evidence on this much-mooted point will be found in the answer of Nature herself, so that an examination of the bed below the head of the distributaries will throw much light on the subject. Taking that portion of the delta below the Forts, which is in a state of nature and unleveed, it is observed that in the reverse curves swinging around these defenses, where the radii are but two and one and one-half miles, the greatest depths are thirty-one and twenty-nine fathoms respectively, due to the reaction of the sharp concave banks and the reduced width. As the radius lengthens to five miles the thalweg depths shoal to thirteen, twelve and eleven fathoms, and the river also widens gradually to the crevasse known as "The Jump," where the width exceeds a half mile and the depths increase to fifteen fathoms abreast of the opening, and to thirty-nine fathoms and "no bottom" at a quarter of a mile *lower down*, with over fifteen fathoms for several miles.

In this instance, therefore, the depth below the crevasse, instead of being less, is more than twice as great, and it is not due to local curvature but apparently to impact, due to the suction or set of the currents toward the right bank.

Continuing down stream as it widens out to a mile in breadth, the bed shoals to about six fathoms at the head of the Passes, which may be regarded as three crevasses, and yet it will be found that in each one of these distributaries the depths exceed those of the undivided stream. In the Pass à l'Outre it is twelve, in South Pass fifteen, and in Southwest Pass thirteen fathoms, with "no bottom," all at the points of incidence of the divided currents. Again in the Pass à l'Outre at the crevasse which formed in 1891, the depth abreast the opening is thirteen fathoms, and one mile below it is fourteen and one-half. This same stream again divides into two main branches, showing eight and one-quarter fathoms below the point of separation in the more direct channel, and eleven and one-half along the sharper concavity of the Southeast Pass, due to reaction of the bank. Without further elaboration, the same general results may be seen wherever a crevasse occurs, and there is no indication of shoaling due to the escape of the excess of the flood waters or loss of volume. On the other hand there is a very marked benefit observable in the relief afforded to the stream, for these openings enable it to discharge a large portion of its sediment beyond the banks

and out of the highway of commerce, which must otherwise be carried to the Gulf and be dropped directly across the channel, thus extending the trough, reducing the slope and increasing the height of the floods. In fact a former Chief Engineer of the State of Louisiana stated that the reason for selecting the Southwest Pass for improvement was because of its greater general depth, so that the shoaling which must result from the extension of the channel four miles by the two jetties would not so soon affect the navigable depths, in consequence of the contraction of the outlet.

As already stated, similar results have taken place in the South Pass above the jetties, where the fill in one place has exceeded forty feet. But these lateral outlets also play an important part in the reclamation of land, as well as in reducing floods and improving navigation, for by this method of hydraulic grading, without cost, large areas are gradually filled and converted into valuable plantations. The extent of these deposits may be roughly determined by a comparison of the United States Coast Survey charts of 1854 and 1884, from which it appears that the accretion to the land above water in the vicinity of the Bayou Grand Liard, Spanish Pass, Red Pass, Tiger Pass, Grand and William's Passes during the thirty years between the surveys amounted to about 113 square miles, or nearly 75,000 acres. At Cubit's Gap, where the river is straight and wide, the rate of deposit has also been considerable. This breach occurred in 1863, and within a few years an area of about eight square miles was raised above water; while a survey made by a Mr. Chucas Lewis in 1892 showed further deposits covering some forty-two square miles, which is already laid out (on paper), under the Government land system, into townships and sections.

A better idea of the extent of this contribution to the wealth of the nation may be obtained by computing the cost of securing it by the usual method of back-filling by the use of hydraulic dredging at, say, ten cents per cubic yard, and assuming the average depth to be nine feet. On this basis the total fill would aggregate some 400,000,000 cubic yards in the thirty years, or over 13,000,000 cubic yards per year. The total cost of securing this result by dredging, regardless of time, would therefore represent $40,000,000 for this one crevasse.

At "The Jump," where 113 square miles were reclaimed in about thirty years, the cost would have been $3,530,000 per annum if attempted by mechanical dredging, or $105,000,000 for the entire

time (or over $1,500 per acre), so that the cost would have been prohibitory. This one deposit, withdrawn from the river, averaged about 35,000,000 cubic yards annually; and as the total amount of sediment carried to the Gulf has been estimated by Humphreys and Abbot at 275,000,000 yards, it represents thirteen per cent. of the whole, while the annual deposit at Cubit's Gap is five per cent.,

Sketch showing Benefits of Crevasses in Reclaiming Land and removing Sediment from Channel
At Cubits Gap 50 sq mls were built up in about 30 years. Av deposits per annum = 12,000,000 cyds removed from bed
Value at 10cts per c.y. = $40,000,000.
Pt. St Philip
Fort Jackson
1862
1903
1904
NORTH PASS
PASS A LOUTRE
NOTES.
The Jump crevasse deposited 113 sq mls. in 30 years - or 35,000,000 c.y. each year, which, @ 10 cts per yard for the 30 years, would have made the cost = $ 105,000,000
These two crevasses discharge about 18 % of the silt annually carried to the Gulf without injury to the navigable channel
Port Eads
SOUTH PASS
SOUTH WEST PASS
DELTA OF THE MISSISSIPPI
Scale, 5m = 1"

making about one-sixth of the sediment which is thus withdrawn by these crevasses, with consequent benefit to navigation, reduction of flood height and increase of the public domain, all without cost.[1]

It would therefore seem that these *lateral outlets* have very much

[1] The depth of three yards was obtained by taking the average of a number of soundings covering the areas filled up by the crevasses (8.7 ft.).

to commend them to the consideration not only of engineers but of economists, business men, farmers and real estate dealers; and that, so far as the evidence of nature goes, their operation is only beneficial and in no wise injurious. If they were closed and the river leveed, all of the advantages named would be destroyed and the sediment would be carried to the mouth, where it would extend the bars more rapidly, raise the flood plain and require elevation of the entire system of levees along the river banks.

But there is another class of outlets which may be considered in this connection, and that is the bars which obstruct the mouths and thus prevent the free discharge of the fluvial waters. These may be distinguished as *longitudinal outlets*, and their permanent removal is entirely practicable by applying the energy of the river to the work to be done.

It is a well known fact that a sedimentary stream, flowing through a straight reach, seldom maintains a single permanent channel, while in swinging around curves the concave bank, acting as the directrix, causes a reaction which deepens the bed and deposits the silt upon the complementary convex bank which is the resultant of this action.

In this way, by the operation of natural laws, the deposits are removed from the path of navigation and the cross-section is automatically adjusted to the requirements of the river. Instead, therefore, of building two parallel jetties as substitutes for the natural banks, and thus extending the river into the Gulf at the expense of its slope and the reduction of its area of discharge along straight lines, which are unnatural and unfavorable, it will be found more rational to build one curved training wall so placed as to create a head and reaction which will transport the silt to the opposite or convex bank, where it will be deposited without cost, leaving an ample navigable channel and saving the expense of one of the jetties, while it also scours away the bar directly in front of the mouth and affords an open passage for the effluent water.

By thus utilizing the tendency of water to flow in curved lines instead of straight ones half the cost of the jetty works may be saved and a better and more permanent channel be obtained, with a lowering of the flood heights of the river. This result is due to the form of the orifice, and it will be seen that when no such modification is applied the effluent stream is abruptly checked by the inertia of the Gulf water and the sediment thus deposited acts as a

buffer to divide and deflect the energy into lateral components, which are again subdivided indefinitely, as shown in the typical forms of the deposits at Cubit's Gap; whereas when supported and concentrated by the continuous reaction of a properly placed resisting medium, the activity of the currents thus generated will prevent deposits near the trace of the work and create a neutral zone or counterscarp at some distance therefrom, which will thus become the site for the dump. These features may be observed wherever there are obstacles placed in the path of a current. The best artificial illustration of the efficacy of this principle as applied to a tidal inlet with a feeble tide is to be found at Aransas Pass, Tex.

The lowering of the flood plain by the removal of the barriers to the longitudinal discharge is also well illustrated by the operations on the River Tyne in England, where the flood heights have been reduced from nine to three feet along the stream by the opening of the mouth and removal of the bars from the bed.

Regardless, therefore, of the interests of navigation, it would be of great benefit to the State and nation to open the mouths of all the Passes for drainage and reclamation purposes, and by the use of the proper form of tool this could be accomplished more effectively and at less cost than by the methods now in vogue at the mouths of sedimentary rivers.

In the foregoing analysis it has been the intention to lay particular stress upon the necessity of so regulating the movements of the sediment as to prevent its being deposited in the pathway of the stream, where it may operate to obstruct its flow, causing elevation of bed, banks, levees and greater risks and expense; for it is evident that so long as the commingled earth and water are confined to the channel with no avenues of escape, the deposits must engorge the bed and involve continuous danger and expense.

It would seem that the attention of the engineering profession has been focussed mainly upon the control of the water, apart from its sediment, and with secondary consideration to the evils resulting from failure to separate these two elements, which, it is believed, may be done to great advantage at a number of points *en route* where lands may be reclaimed by the natural process of hydraulic grading, and large tracts of the richest arable land be recovered in a comparatively short time at a cost which will be insignificant as compared with that required to grade and drain it by mechanical means.

It is therefore desired to direct particular attention to the necessity of providing suitable dumping sites for the mud carried seaward by the river in times of flood, where it may be deposited beyond the banks of the stream without injury, through or over suitable weirs, and be retained by impounding dikes in the low swampy regions to their advantage.

The question is similar in its general features and effects to that prevailing at the inlets along alluvial coasts, where it was the practice to attempt the removal of the bars by jetties in pairs, supplemented by dredging; but which method has not been able to meet fully the demands of modern vessels, so that recourse is now being had to the control of the heavier earthy materials which compose these obstructions, in such manner as to protect the channels from their encroachments and cause the single concave jetty to construct and maintain much greater depths than exist in a state of nature.

Stated Meeting, March 18, 1904.

President SMITH in the Chair.

A letter was read from the Marquis de Nadaillac accepting his appointment as the Society's representative at the celebration of the Centenary of the Société Nationale des Antiquaires de France.

The decease was announced of William Marriott Canby, of Wilmington, Del., on March 10, 1904, æt. 73.

Prof. Felix E. Schelling read a paper on "The Academic Drama in the Age of Elizabeth and James."